INSTRUCTION MANUAL
1503L-M

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California Instruments

INSTRUCTION MANUAL
1503L-M

Invertron®

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SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

This instruction manual contains information on the installation, operation, calibration, and maintenance of the California Instruments Model 1503L-3M AC Power System.

1.2 SPECIFICATIONS

Table 1-1 contains the operating specifications of the 1503L-3M AC Power System. All specifications are tested in accordance with standard California Instruments test procedures. The following specifications apply for operation at 100% of full scale voltage, using external sense, 25 ±1°C, after 15 minute warm-up and under constant line and load conditions.

TABLE 1-1
OUTPUT SPECIFICATIONS

Total power: 1667 VA at 100% of voltage range at 35°C.
1500 VA at 100% of voltage range at 50°C.

Power/phase: 556 VA at 100% of voltage range at 35°C.
500 VA at 100% of voltage range at 50°C.

Power factor: 0 to 1.0.

Current/phase:

135V RANGE		270V RANGE	
35°C	50°C	35°C	50°C
4.12	3.70	2.06	1.85

For other voltage ranges: Current per Phase = VA (per phase)/voltage range

Peak repetitive current per phase: 250% of the current rating at 50°C

Peak nonrepetitive current per phase:
270% of the current rating at 50°C (10 milliseconds).

Voltage range: 0 and 270 (Standard)
67.5 and 135 (LV Option)
156 and 312 (HV Option)
200 and 400 (EHV Option)

Total Distortion (to 300 kHz, at full-scale voltage driving full linear load):
1% from 45 Hz to 2 kHz,
2% from 2 kHz to 5 kHz.

OUTPUT SPECIFICATIONS (continued)

Line regulation: 0.02% for ±10% line change.

Load regulation: 0.05% no load to full load.

Frequency range: 45* Hz to 5 KHz (at a 50°C maximum current only)
45* Hz to 1 KHz (EHV option)
45* Hz to 2 KHz at 35°C maximum current

Frequency Resolution: 0.1 Hz to 99.9 Hz
1 Hz from 100 to 999 Hz
0.01 KHz from 1.0 to 5.00 KHz

Frequency accuracy (at 25 degrees C):
±0.005% of programmed value.

Phase angle accuracy: (each phase similarly loaded)

Phase B and C realitve to Phase A: ±3 degrees

PROTECTION

Output overload:	Will operate at a constant current for an overcurrent condition
Output short circuit:	Immediate shutdown
Invalid Frequency:	Immediate shutdown to 0 volts
Input Overvoltage:	Causes a trip of the circuit breaker
Sense line fault:	The output ovltage increases 15%
OverTemperature:	Shutdown to 0 volts with automatic restart
Loss of Input Phase:	No output for loss of Phase B or C. Normal operation at reduced power with loss of Phase A.

MEASUREMENTS (at 25°C ambient)

Front Panel analog voltmeter. Accuracy ±5% of reading.

NOTE(*): Operation down to 17 Hz at reduced output voltage

SUPPLEMENTAL SPECIFICATIONS

LINE INPUT

Voltage: 103 - 127 vac,
206 - 254 vac.

Current: 27 amps max.

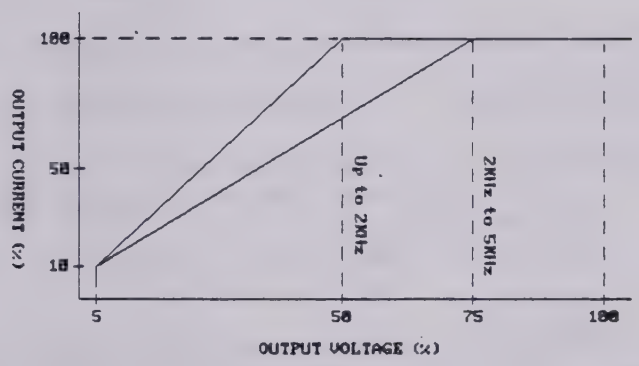
Frequency: 47 - 440 Hz.

Efficiency: 75% typical.

Surge current (turn-on): 185 amps max.

SUPPLEMENTAL OUTPUT SPECIFICATIONS

Full current range:



Output noise (20 kHz to 1 MHz): 60 millivolts rms (typical)

Voltage temperature coefficient: ±0.02V/degree C.

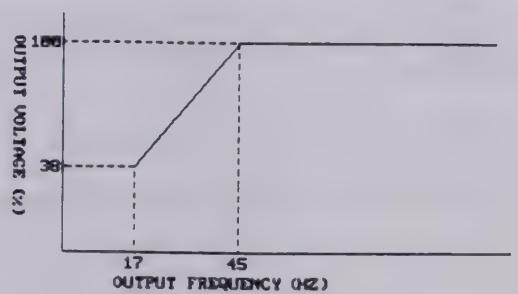
Voltage stability (24 hours, constant line, load and temp.):

±0.015% of full scale.

Steady-State Output Impedance (ohms)

= (Voltage Range) x (0.0005)/Full-load current

Frequency Range
At less than Full Scale Voltage: (Refer to graph below)



SUPPLEMENTAL OUTPUT SPECIFICATIONS (continued)

Frequency Temperature Coefficient: ±5 ppm of value per °C

Frequency Stability: ±15 ppm of value per year

Isolation (line input to output): greater than 500 vrms.

Front panel controls:

Power on/off circuit breaker

Current Limit: 1-turn pot for 0 to 100% of rated output current

Frequency: 3-turn roatary switches. 3-position toggle switch for Frequency Range

Voltage Amplitude: Varied by 10-turn pot

Voltage Range: HI/LO set by toggle switch

Remote Shutdown: A logic Low input will program the voltage to 0 and open the Output Relays

External Sense: Compensates for up to a 10% drop in the load lines.

External Modulation: An input of 0 to 10V rms and DC to output frequency generates 0 to 10% amplitude modulation

Indicators: Output Overload, Overtemperature, Power On, High Voltage range, Frequency Fault, 300 volt analog meter with 5% accuracy.

Dimensions: Width - 19" (48.3 cm).
Height - 5.25" (13.3 cm).
Depth - 23.1" (58.7 cm).

Weight: 85 lbs (38.6 kg).

Material: aluminum - front panel, top cover.
steel - rear panel, chassis.

Finish: front panel - painted gray 26440 per Fed Std 595.
steel - zinc plate type 2, class 2.
aluminum - iridite.

Air intake/exhaust: intake from sides, exhaust to rear.

Modularity: modular construction of all major assemblies.

SUPPLEMENTAL SPECIFICATIONS (continued)

Connectors:

Input - Kulka 9-85-3.

Output - Kulka 3695A-8.

Sense - Amp 1-480705-0
with Amp 350689-1 socket contacts.

Sense mate - Amp 1-480704-0
with Amp 350690-1 pin contacts.

Interface - 3M 3367-1000 socket.

Interface mate - 3M 3366-1001 plug.

Chassis slides: Zero Manufacturing CTN-1-20-E94.

Operating temperature: 0 to 50 degrees C.

Storage temperature: -40 to 85 degrees C.

Operating altitude: 0 to 6000 feet (0 to 1830 meters).

OPTIONS

LK: Allows unit to be operated as a master (LKM option) or slave (LKS option) in synchronization with other California Instruments controllers. The LK option cannot be used if the AX option is installed.

LV: Low voltage output; 0 to 67.5 Vrms/0 to 135 Vrms.

HV: High voltage output; 0 to 156 Vrms/0 to 312 Vrms.

EHV: Extra High Voltage output; 0 to 200Vrms/0 to 400Vrms.

2P: Two phase output; Phase B is disabled and Phase C is set to 90 degrees with respect to Phase A.

AX: Auxiliary outputs; provides low power fourth and fifth phases, D and E. The AX option cannot be used if the LK option is installed.

(All specifications at 25°C and verified with TRMS voltmeter. The Phase D sense lines must be connected to the Phase D output.)

OPTIONS (continued)

Phase D

Voltage: 26.0 Vrms ±2%, fixed.

Current: 3.0 Arms, max.

Frequency: 360 to 440 Hz (tracks main outputs).

Phase: Tracks Phase A.

Phase accuracy: ±2 degrees, all outputs at half load.

Distortion: 1%, maximum with linear load.

Line regulation: ±0.05% using external sense.

Load regulation: ±0.05% using external sense.

Phase E

Voltage: 5.0 Vrms ±5%, fixed.

Current: 5.0 Arms, max.

Frequency: 360 to 440 Hz (tracks main output).

Phase: Tracks Phase A.

Distortion: 1% maximum with linear load.

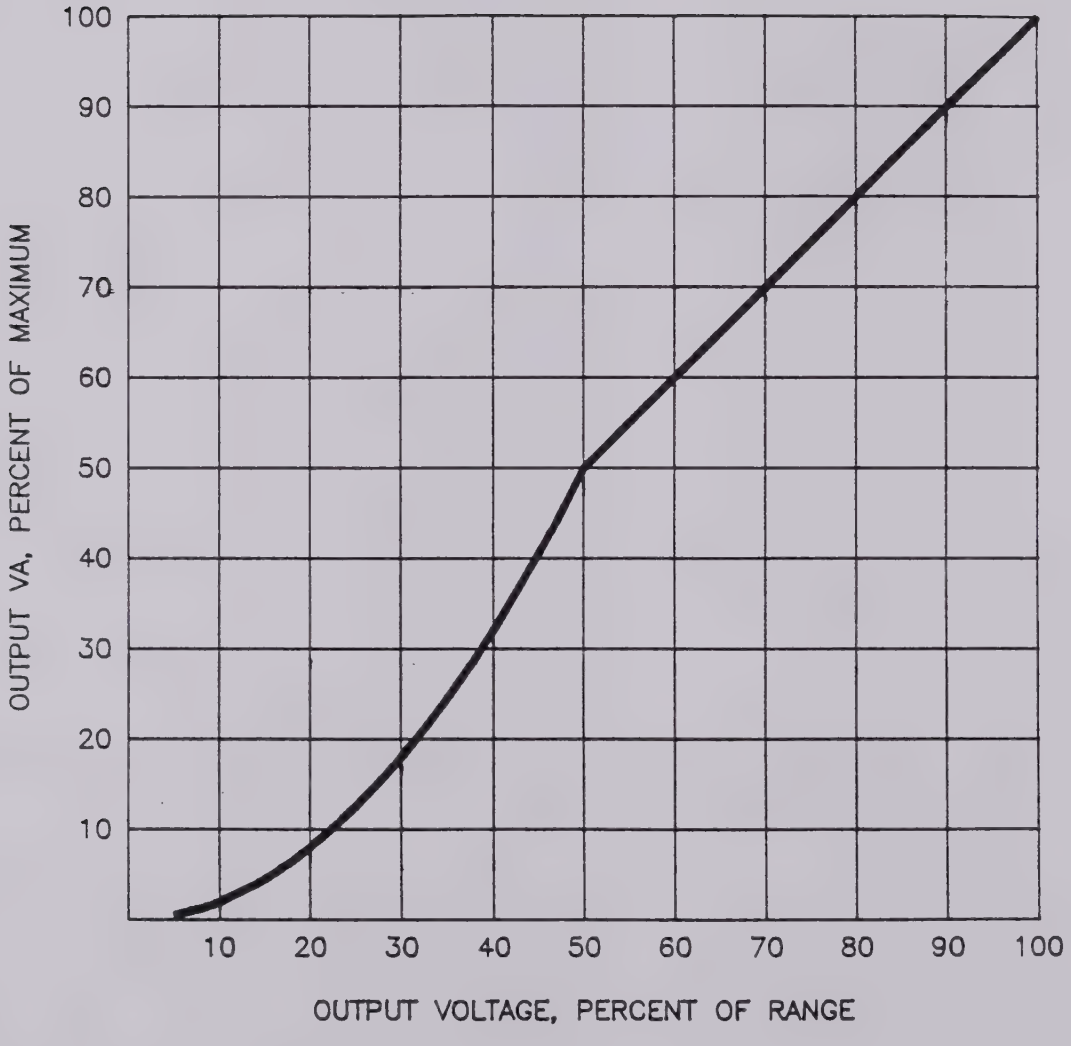
Line regulation: ±0.1%.

Load regulation: ±10%.

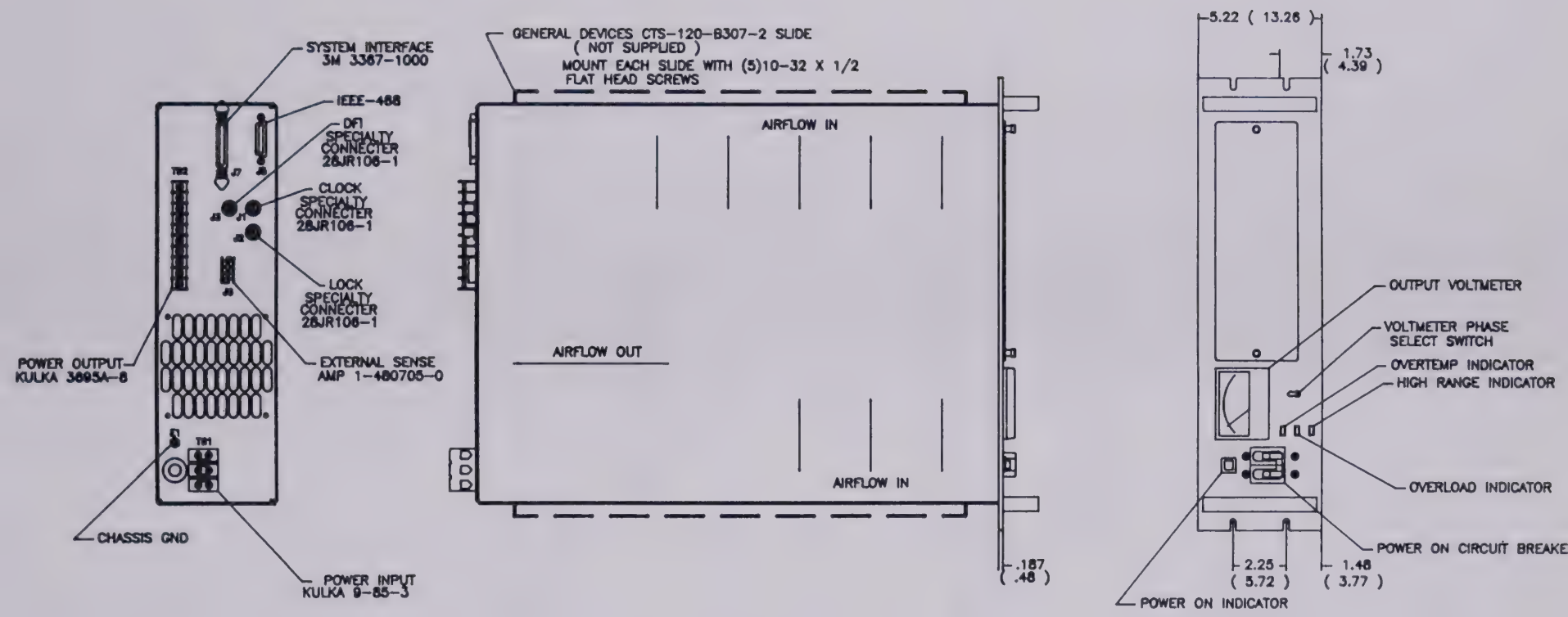
RPV: 0 to +10 VDC input for 0 to full-scale output voltage. This option is not availabe with External Modulation.

1.3 GENERAL DESCRIPTION

The California Instruments Model 1503L-3M is a high efficiency, low distortion power source that provides up to 1667 VA three phase power. The 1503L-3M is illustrated in Figure 1-1. Full power output is available in two voltage ranges and over the frequency range from 45 Hz to 2000 Hz. 1500VA three-phase power is available from 45 Hz to 5000 Hz. The EHV option is limited to 1000 Hz.



OUTPUT POWER CURVE



OUTLINE DRAWING

FIGURE 1-1

CAUTION

Voltages up to 480 VAC are available in certain sections of this power source. This equipment generates potentially lethal voltages.

DEATH

on contact may result if personnel fail to observe safety precautions. Do not touch electronic circuits when power is applied.

SECTION 2

INSTALLATION AND ACCEPTANCE

2.1 UNPACKING

Inspect the unit for any possible shipping damage immediately upon receipt. If damage is evident, notify the carrier. DO NOT return an instrument to the factory without prior approval.

Do not destroy the packing container until the unit has been inspected for damage in shipment.

2.2 POWER REQUIREMENTS

2.2.1 AC LINE VOLTAGE

The 1503L power source has been designed to operate from either of the following AC line voltage ranges:

1) 103 to 127 volts
2) 206 to 254 volts.

CAUTION

The 1503L will be damaged if it is operated at an input voltage that is outside its configured input range.

The input voltage range is set at the factory. Section 2.3 gives the procedure to change the input voltage range.

2.2.2 LINE FREQUENCY OPERATING RANGE

The 1503L power source has been designed to operate over the line frequency range from 47 Hz to 440 Hz.

2.2.3 INPUT POWER

The input power to the 1503L power source depends upon line and load conditions and may be as high as 2300 watts.

2.3 INPUT VOLTAGE RANGE SELECTION

WARNING

Voltages up to 360 VDC and 270 VAC are present in certain sections of this power source. This equipment generates potentially lethal voltages.

DEATH
on contact may result if personnel fail to observe safety precautions. Do not touch electric circuits when power is applied. Servicing should only be performed by trained personnel.

The input voltage range is configured by two wires and eight jumpers. See Figure 2-1 for the location of these components.

2.3.1 LOW INPUT VOLTAGE RANGE CONFIGURATION

Remove input power at the rear panel of the power source before attempting to change the voltage range configuration.

The low input voltage range is set by making the following connections inside the power source:

Wire 4008-050-005	From CB1B-LN to A4-E2.
Wire 4008-050-011	From DS1 to A4-E7.
Jumper A4-J1	From 2 to 5.
Jumper A4-J1	From 3 to 4.
Jumper A4-J2	From 2 to 5.
Jumper A4-J2	From 3 to 4.
Jumper A4-J3	From 2 to 5.
Jumper A4-J3	From 3 to 4.
Jumper A4-J4	From 2 to 5.
Jumper A4-J4	From 3 to 4.

2.3.2 HIGH INPUT VOLTAGE RANGE CONFIGURATION

Remove input power at the rear panel of the power source before attempting to change the voltage range configuration.

The high input voltage range is set by making the following connections inside the power source:

Wire 4008-050-005	From CB1B-LN to CR1-AC.
Wire 4008-050-011	From DS1 to A4-E4.
Jumper A4-J1	From 1 to 6.
Jumper A4-J1	From 2 to 3.
Jumper A4-J2	From 1 to 6.
Jumper A4-J2	From 2 to 3.
Jumper A4-J3	From 1 to 6.
Jumper A4-J3	From 2 to 3.
Jumper A4-J4	From 1 to 6.
Jumper A4-J4	From 2 to 3.

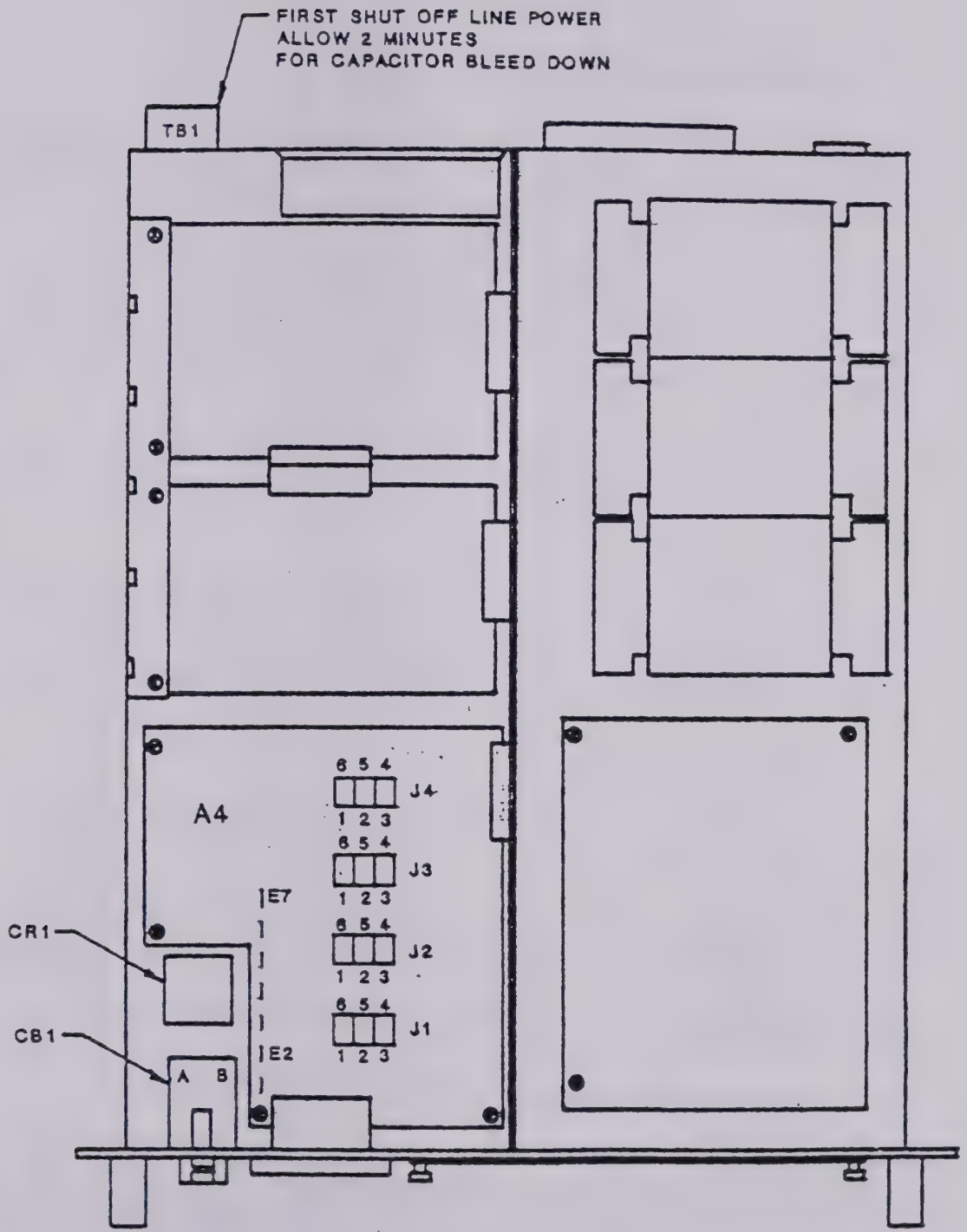


FIGURE 2-1

1503L INPUT VOLTAGE RANGE SELECTION

2.4 MECHANICAL INSTALLATION

The 1503L power source has been designed for rack mounting in a standard 19 inch rack. The unit should be supported from the bottom with a shelf-track or supported from the sides with optional rack slides.

The cooling fan at the rear of the unit must be free of any obstructions which would interfere with the flow of air. A 2.5 inch clearance should be maintained between the rear of the unit and the rear panel of the mounting cabinet. Also, the air intake holes on the sides of the power source must not be obstructed. See Figure 2-2. Special consideration of overall air flow characteristics and the resultant internal heat rise must be allowed for with systems installed inside enclosed cabinets to avoid self heating and over temperature problems.

2.5 INPUT WIRING

The 1503L power source must be operated from a three-wire single phase service. The required mains voltage is divided in two ranges. See Section 1.2 for the input voltage ranges. The mains source should have a current rating greater than or equal to the power source circuit breaker rating, 30 amps.

2.6 OUTPUT CONNECTION

The output terminal block, TB2, is located at the rear of the 1503L power source. All load connections must be made at TB2.

The remote sense inputs allow the power source output voltages to be monitored directly at the load and must be connected. The remote sense wires are connected at J6 on the 1503L rear panel.

See Figure 2-2 for the location of the output terminal block and remote sense input.

2.6.1 OUTPUT POWER WIRING

The output power cables must be large enough to avoid excessive voltage drops due to the impedance of the wires. The voltage drop across the cables should be limited to 2 percent of the 1503L power source output voltage. Table 2-1 lists the minimum acceptable wire size for a 1 percent line drop assuming a symmetrical load located 10 feet from the power source. The line drop listed in the table is due only to the resistance of the wire. At higher power source output frequencies, reactive losses may increase the line voltage drop. To reduce high frequency effects, bundle wires tightly together.

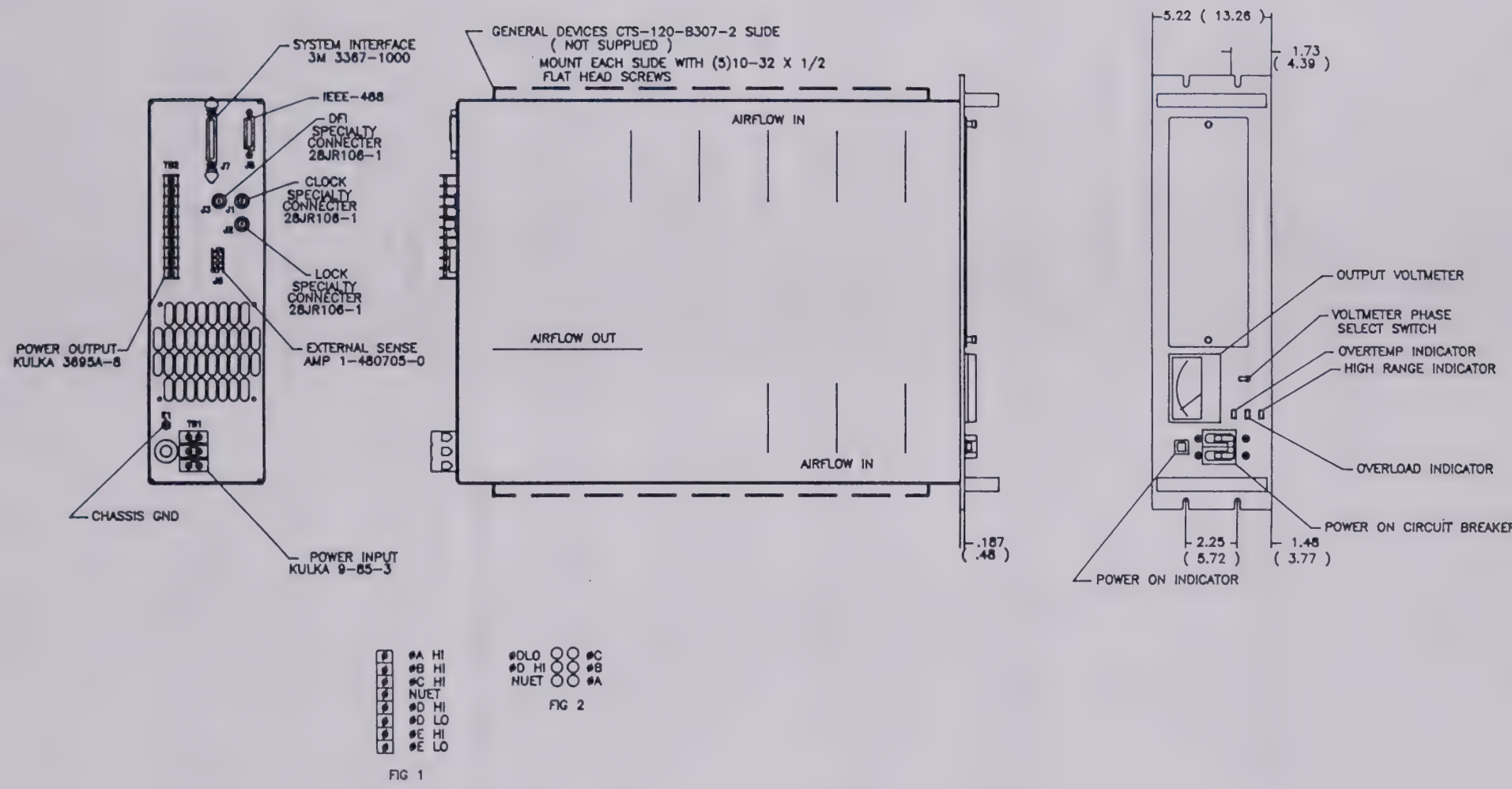


FIG 1

FIG 2

FIGURE 2-2

CALIFORNIA INSTRUMENTS 1503L

TABLE 2-1
MINIMUM WIRE SIZE
FOR 1 PERCENT LINE DROP

OUTPUT VOLTAGE	MAXIMUM LINE DROP	MAXIMUM PER PHASE CURRENT	LOOP LENGTH	MINIMUM REQUIRED WIRE GAUGE
Volts	Volts	Amps	Feet	AWG
135	1.35	4.12	20	22
270	2.70	2.06	20	28

The wire sizes specified in Table 2-1 are for single wire bundles and reflect the MINIMUM wire size required. If wires are in large bundles or are in confined spaces, the wire sizes should be doubled (wire gauge reduced by 3 wire gauge numbers).

NOTE

The wire gauge should be reduced by 3 wire gauge numbers for every time that the distance is doubled between the power source and the load. For example, use AWG 19 when operating on the 135 volt range with a load 20 feet from the power source.

2.6.2 REMOTE SENSE WIRING

The remote sense lines of the 1503L must be connected at all times for proper operation. Failure to connect the sense wires will prevent the power source from meeting its line load regulation specifications.

The remote sense lines are connected to the 1503L power source using the connectors listed in Section 1.2 of this manual. The remote sense wires should be AWG 22 or larger. See Figure 2-2.

2.7 OUTPUT VOLTAGE RANGES

The 1503L is configured to operate on one of two possible voltage ranges, a high range and a low range. Activation of the high range is indicated on the front panel when the "HIGH RANGE" lamp is illuminated. No lamp is lit to indicate the low range.

The output range is set by a toggle switch on the front panel. The low range is selected when the voltage range switch is in the lower position; the high range is selected when the switch is in the upper position.

Each time the output voltage range is changed, the output voltage is momentarily set to zero to reduce relay contact wear.

CAUTION

Before a range change is made, verify that the output voltage and load are compatible and within the VA ratings of the 1503L, or damage to the load may occur.

2.8 FRONT PANEL CONTROLS

2.8.1 CIRCUIT BREAKER

The circuit breaker is used to switch power to the unit. When the circuit breaker is switched ON, the amber indicator lamp above the circuit breaker illuminates. See Figure 2-3.

2.8.2 VOLTMETER SELECTOR SWITCH

A voltmeter selector switch is located just below the front panel voltmeter. The three position switch changes the signal applied to the voltmeter among the three 1503L output phases. When the switch is to the top, Phase A is selected, in the middle, Phase B is selected, and down, Phase C is selected. See Figure 2-3.

2.8.3 FREQUENCY SELECT SWITCHES

Three 10-position rotary switches set the three digits of frequency.

2.8.4 FREQUENCY RANGE SWITCH

A three position toggle switch sets the frequency range to LOW (45 to 99.9 Hz), MID (100 to 999 Hz) and HIGH (1 to 5 KHz).

2.8.5 VOLTAGE RANGE SWITCH

A two-position toggle switch sets the voltage range to LO (0-135 volts rms) or HIGH (0-270 volts rms).

2.8.6 AMPLITUDE POTENTIOMETER

A 10-turn potentiometer sets the output voltage amplitude between 0% and 100% of output range.

2.8.7 CURRENT LIMIT POTENTIOMETER

A single-turn potentiometer sets the programmable current limit point between 0% and 100% of maximum output current for the selected voltage range.

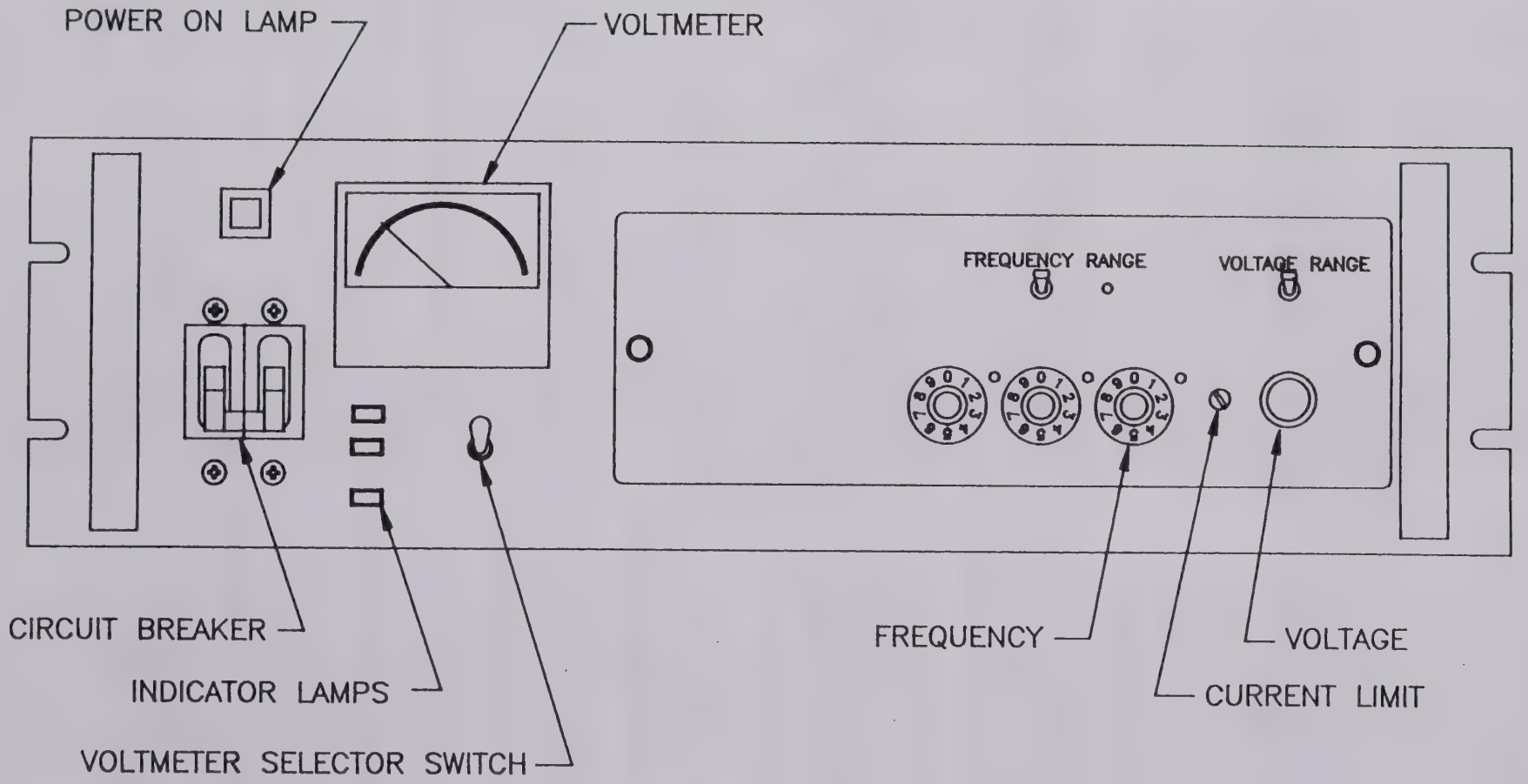


FIGURE 2–3
1503L–M FRONT PANEL

2.9 FUNCTION TEST

2.9.1 INITIAL SETUP

Refer to Figure 2-4 for the recommended test setup. Ensure that the AC mains are of the proper voltage and frequency. Use #10 wire to connect the AC power line to the AC input terminal block, TB-1.

2.9.2 POWER ON

1) Apply AC line power to the 1503L power source.

2) Apply input power to the 1503L power source by setting the front panel circuit breaker to the "ON" position. At this time, no loads should be connected to the output terminal block, TB-2.

3) Verify that the POWER lamp is lit.

2.9.3 RANGE SWITCHING

1) Set the voltage range to high range. The HIGH RANGE lamp should be lit.

2) Set the power controller to 400 Hz. Adjust for 270 volts. Verify that the front panel voltmeter indicates 270 volts for all three phases.

3) Change the voltage range to low range. The HIGH RANGE lamp should extinguish.

4) Adjust the power controller for 135 volts. Verify that the front panel voltmeter indicates 135 volts for all three phases.

2.9.4 NO LOAD/FULL LOAD/OVERLOAD TEST

NOTE: The following test calls for a 556 VA load on the 135 volts range. To calculate the load for another voltage range use the formula:

$$\text{LOAD(ohms)} = (\text{Voltage Range})^2 / 556$$

1) Observe each of the three outputs with the oscilloscope or distortion analyzer. The outputs should be clean sine waves having less than 1.0% distortion.

2) Apply full loads to each phase (32.7 ohms, 556 watts each). Verify that the voltage of each phase remains within 0.05% of the no-load voltage. The waveforms shall still appear clean on the oscilloscope and should contain less than 1% distortion. The OVERLOAD lamp should not be lit.

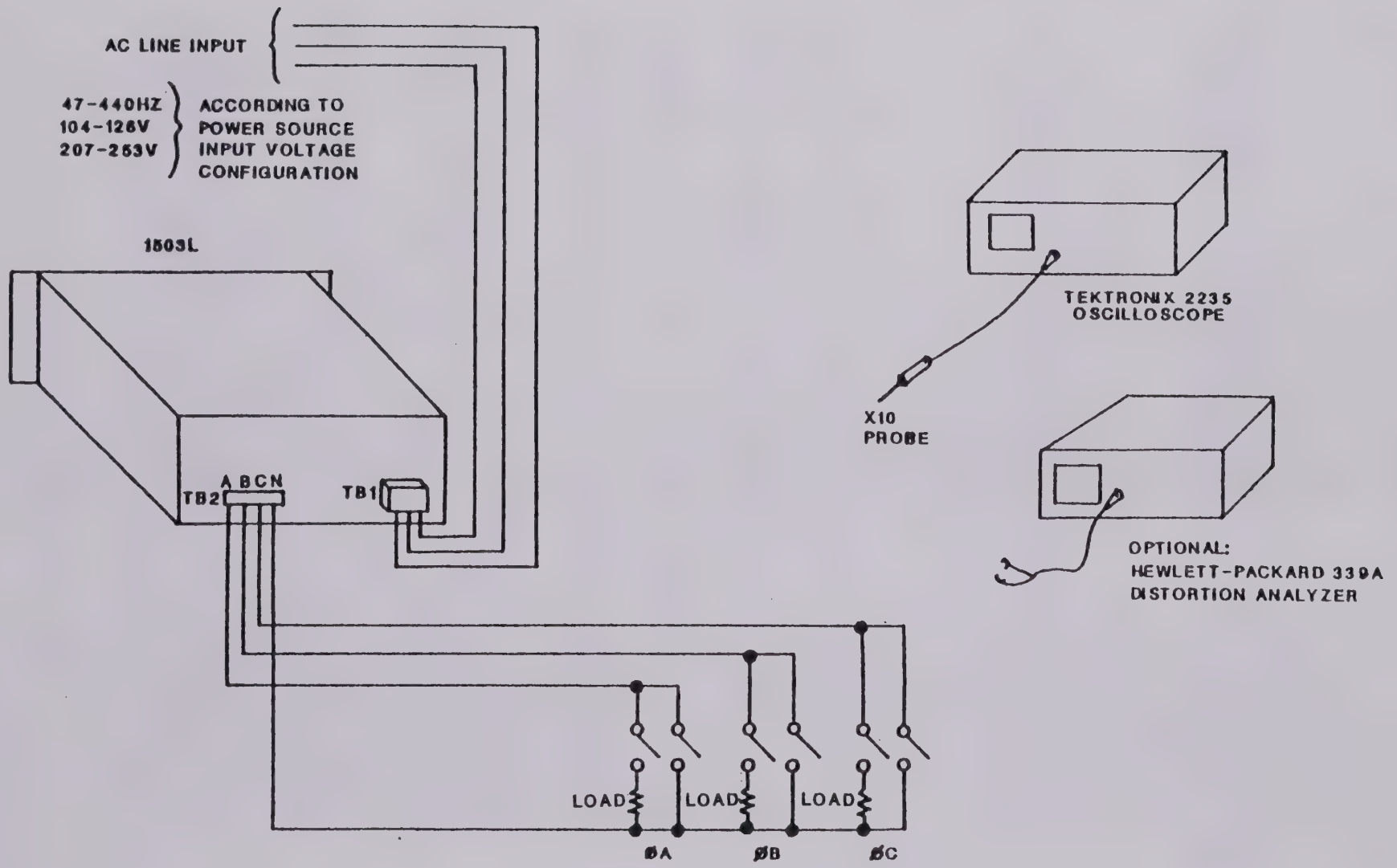


FIGURE 2-4

1503L FUNCTION TEST SETUP

3) Remove the loads. Apply a short circuit for several seconds to the Phase A output. Remove the short circuit; the output shall recover to the original no-load voltage.

4.) Repeat step 3 for the phase B output and then the phase C output.

2.9.5 ADDITIONAL TESTS

1) Sections 2.9.3 and 2.9.4 may be repeated for any phase at any rated voltage and frequency within the specified load limits of the 1503L.

2) The Calibration Procedure in Section 4 of this manual should be used if more detailed evaluation of the 1503L is required.

SECTION 3

OPERATION

3.1 GENERAL

The California Instruments 1503L is a three-phase high efficiency AC power source. The power source consists of three separate, identical amplifiers, see Figure 3-1. The amplifiers share a common ground referenced input and a common but floating output neutral.

3.1.1 INPUT DRIVE

The amplifier drive signals to the 1503L are generated by an internal controller. The input drive is set by a 10-turn potentiometer on the power source front panel.

3.1.2 OUTPUT VOLTAGE RANGES

The output voltage of the 1503L may be adjusted to any value within the range of the unit. Rated output VA and conversion efficiency is greatest when the output voltage is set near maximum. For this reason, the 1503L is designed to operate on one of two ranges, 135 volts full scale, or 270 volts full scale. The user should choose the range that allows operation nearest 100% of maximum voltage of the selected range. All three phases operate on the same range and switch simultaneously.

3.1.3 OUTPUT VA CAPABILITY

The output drive capability of each amplifier is limited by VA, volt-amps, rather than power, watts. An amplifier can drive a capacitive or inductive load to its full VA rating without delivering any power to the load.

The amount of VA available to a load may be determined from Figure 3-2, the output power curve. The output power curve rates available VA versus output voltage; it is a straight line between 50% and 100% of output voltage range (constant current) and a curve between 5% and 50% of output voltage range (linearly derated current versus voltage). Full VA is available only at full scale voltage. Full current is available at voltages between 50% and 100% of output voltage range.

The amplifier load may draw full VA at any power factor between 0 and +1 and may draw maximum current with a crest factor up to 2.5. (Crest factor is the ratio of peak current to rms current.) If the load draws current in excess of the maximum rated average or in excess of the rated crest factor, the amplifier will clip the voltage waveform to prevent excessive internal power dissipation.

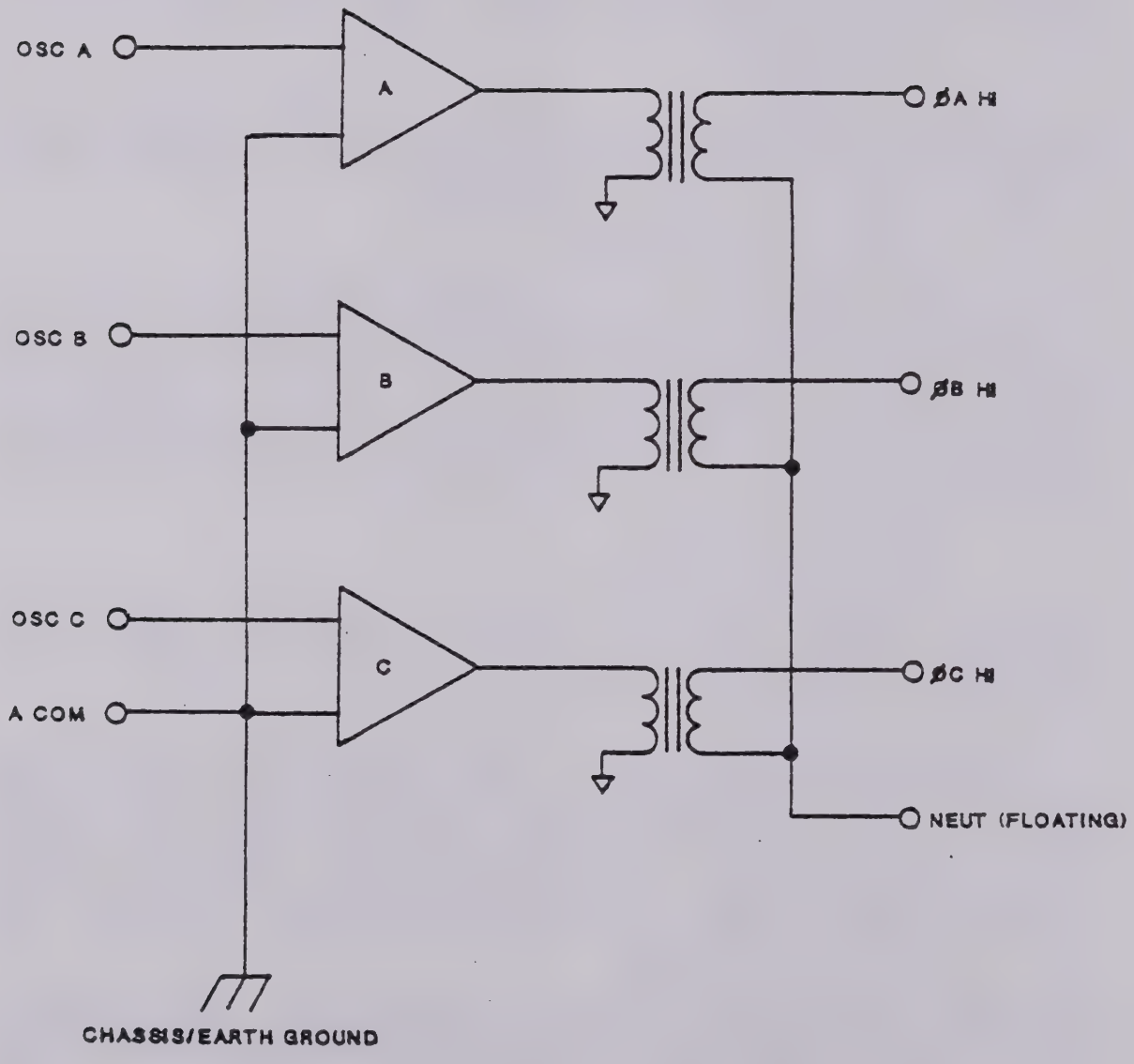


FIGURE 3-1

1503L THREE PHASE AMPLIFIER

3.2 FRONT PANEL CONTROLS, INDICATORS

Refer to Figure 3-3 for an illustration of the 1503L front panel.

CIRCUIT BREAKER:

The circuit breaker switches power to the 1503L. In the event that a fault within the power source causes an excessive draw of current, the circuit breaker will trip.

POWER ON LAMP:

The POWER lamp illuminates when the circuit breaker is switched on and the 1503L begins to draw input power.

VOLTMETER:

This average responding AC voltmeter is switched directly to the power source outputs. Full scale deflection is 300 volts. The voltmeter will indicate no voltage if the output relays are open.

METER SELECT SWITCH:

This three position switch selects which of the three phases will be displayed by the voltmeter. The upper position selects Phase A, the middle position selects Phase B, the lower position selects Phase C.

INDICATOR LAMPS:

OVERTEMP: This lamp illuminates when the temperature of a power amplifier heatsink has surpassed a maximum set level. The overheated amplifier will shut down until its heatsink has cooled to a safe temperature. The amplifier will then automatically recover.

OVERLOAD: This lamp illuminates when the power source has limited the outputs during a programmable current limit fault. Clipping of the output waveform will occur until the load current drops below the programmable current limit set level.

HIGH RANGE: This lamp illuminates when the power source has switched to its high voltage range setting.

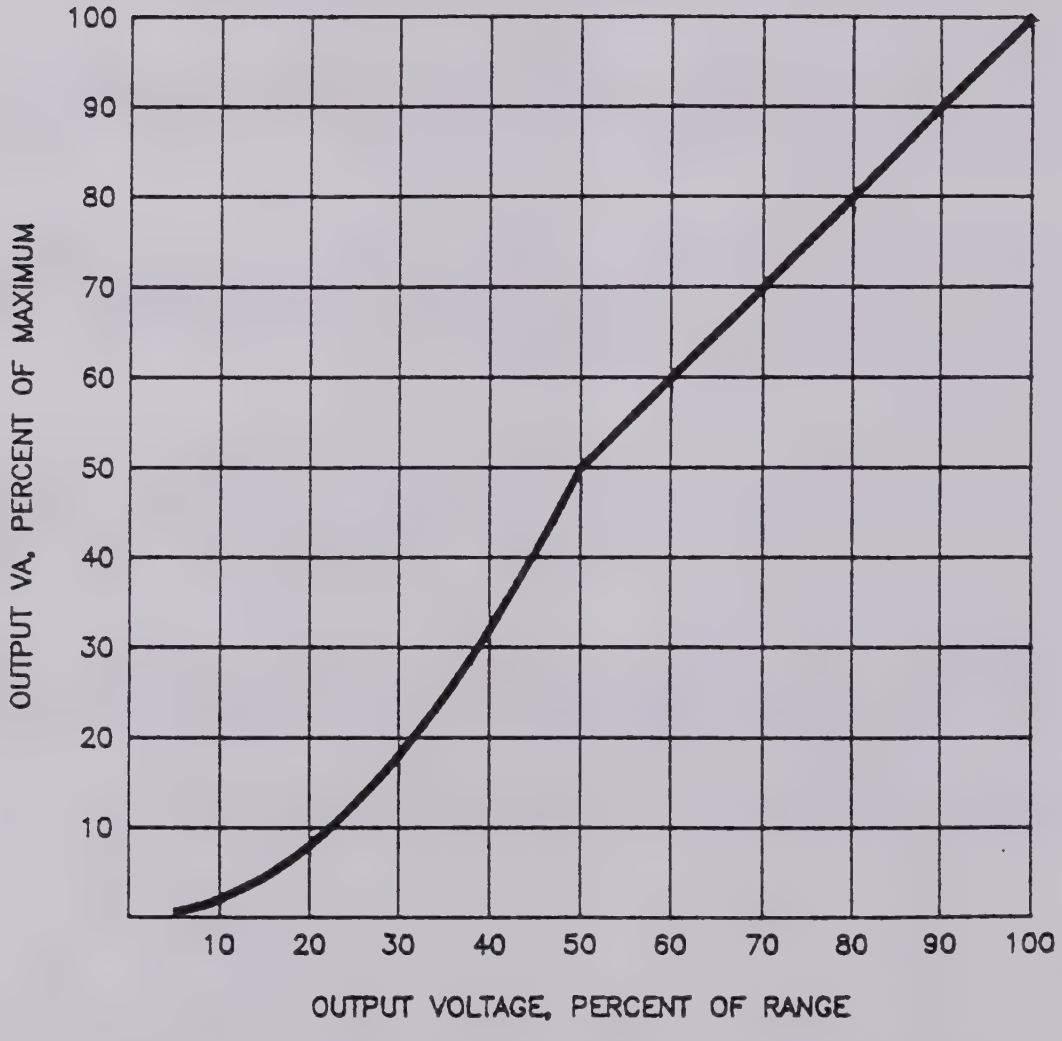


FIGURE 3-2 OUTPUT POWER CURVE

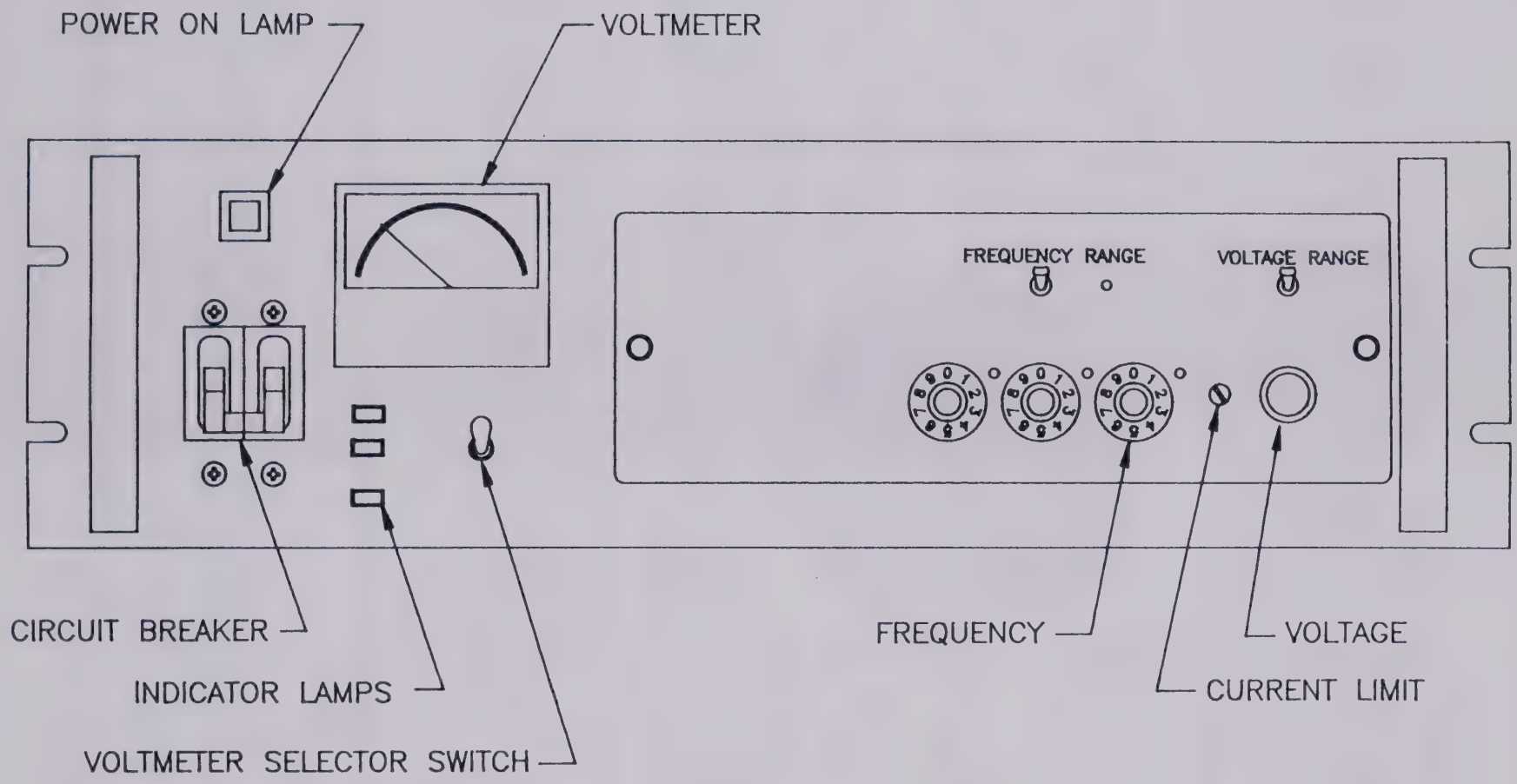


FIGURE 3–3
1503L–M FRONT PANEL

CONTROLLER PANEL:

FREQUENCY SELECT DIALS: These three dials set the output frequency within the range set by the Frequency Range Select switch. When in the 45.0 to 99.9 Hz range, an LED decimal point is lit between the second and third dials to give 0.1 Hz resolution. When in the 100 to 999 range an LED decimal point is lit after the third dial to indicate 1 Hz resolution. When in the 1.00 to 5.00 KHz range, an LED decimal point is lit between the first and second dials to give 0.01 Hz resolution.

FREQUENCY RANGE SELECT: This three-position switch selects which of the three ranges the frequency select dials will use. The lower position selects the 45.0 to 99.9 Hz range. The middle position selects the 100 to 999 Hz range. The upper position selects the 1.00 to 5.00 KHz range.

VOLTAGE AMPLITUDE Knob: This knob simultaneously sets the amplitude of all three phases between zero and full scale of the selected voltage range.

VOLTAGE RANGE Switch: This range select switch sets the output voltage to the low range when in the lower position and to the high range when in the upper position.

CURRENT LIMIT Knob: This knob sets the programmable current limit to all phases simultaneously. Turning the knob fully counterclockwise sets the current limit to zero amps, fully clockwise sets the current limit to the maximum capability of the selected voltage range. The knob sets the limit linearly between the two extremes.

LIMIT Lamp: This red LED is lit when the power controller is limiting its oscillator drive signals. This occurs for a very short time when power is initially applied or when its voltage range is changed. The LED stays on indefinitely if the output frequency is set above or below the capabilities of the power source or while the REMOTE ON line is held low.

3.3 REAR PANEL INTERFACE

Refer to Figure 3-4 for an illustration of the 1503L rear panel.

3.3.1 TB1 POWER INPUT

TB1-HI: This is the HI input power voltage terminal. Connect only to voltages corresponding to the input configuration. The service rating must be 30 amps or greater.

TB1-LO: This is the return for the TB1-HI line.

TB1-GND: This is the chassis ground connection and must be connected to earth ground.

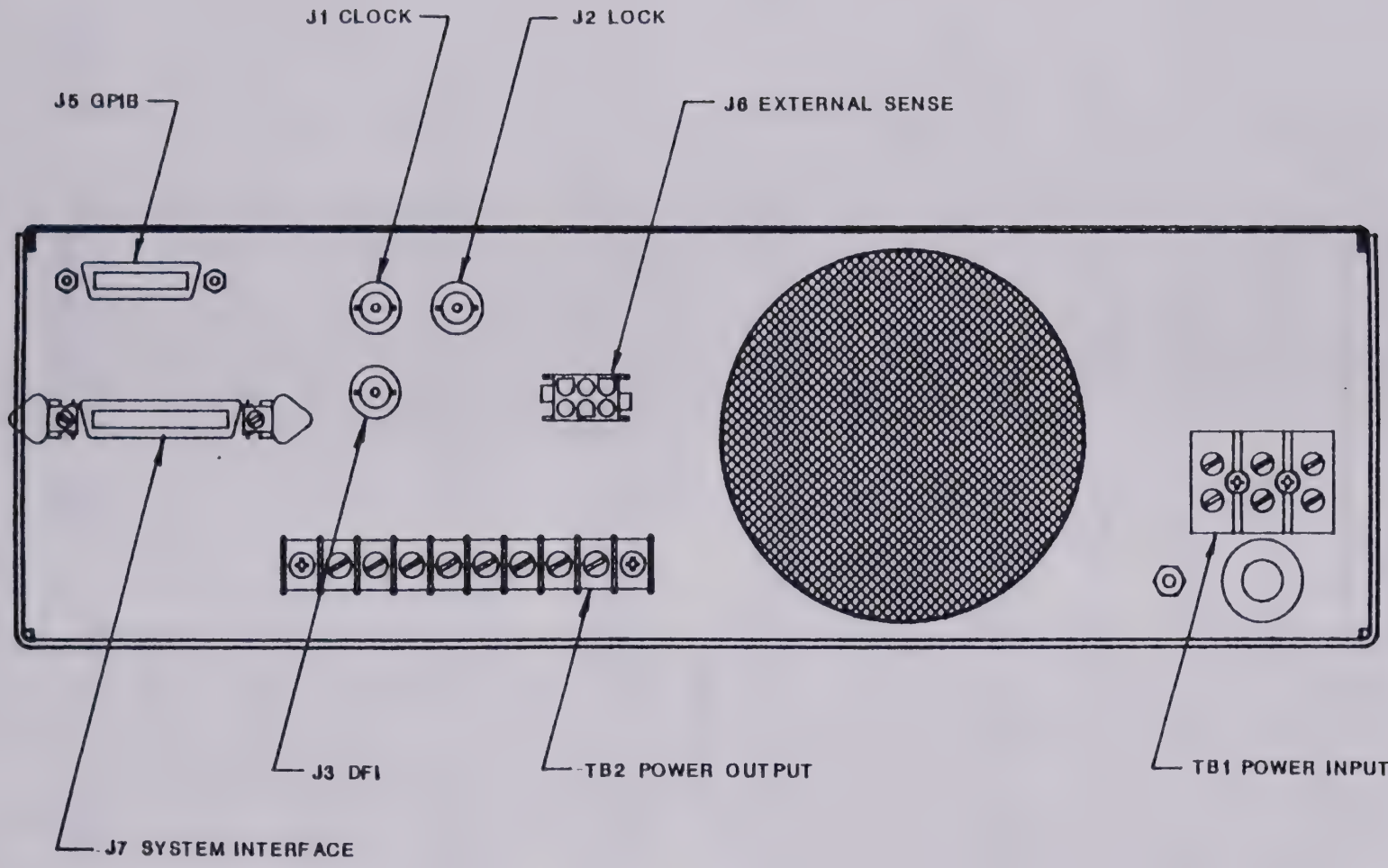


FIGURE 3-4
1503L REAR PANEL

3.3.2 TB2 POWER OUTPUT

TB2-1: This is the Phase A output terminal. Use TB2-4 for the return.

TB2-2: This is the Phase B output terminal. Use TB2-4 for the return.

TB2-3: This is the Phase C output terminal. Use TB2-4 for the return.

TB2-4: This is the floating neutral line for Phases A, B, and C.

TB2-5: This is the Phase D output terminal for the AX option. Use TB2-6 for the return.

TB2-6: This is the floating Phase D neutral for the AX option. This neutral is common with the Phase E neutral.

TB2-7: This is the Phase E output terminal for the AX option. Use TB2-6 for the return.

TB2-8: This is the floating Phase E neutral for the AX option. This neutral is common with the Phase D neutral.

3.3.3 J1 CLOCK

This signal is used by California Instruments power controllers to synchronize oscillators in multiple power source systems. The connector is installed as an option.

3.3.4 J2 LOCK

This signal is used by California Instruments power controllers to synchronize oscillators in multiple power source systems. The connector is installed as an option.

3.3.5 J3 DFI

Not used.

3.3.6 J5 GPIB

Not used.

3.3.7 J6 EXTERNAL SENSE

The external sense lines allow the output voltages to be sensed at the load to account for impedance losses in output wiring. The Phase A, B, C, and NEUT lines must be connected to the output if an internal power controller is used. The Phase D HI and Phase D LO lines must be connected if the AX option is installed.

J6-1: Phase A High sense.

J6-2: Phase B High sense.

J6-3: Phase C High sense.

J6-4: Phase A, B, C Neutral sense.

J6-5: Phase D High sense.

J6-6: Phase D Low sense.

3.3.8 J7 SYSTEM INTERFACE

The system interface connector must be used to provide oscillator and control signals for power sources configured without an internal power controller.

J7-1, A COM: Analog common reference/return.

J7-2, not used.

J7-3, A COM: Analog common reference/return.

J7-4, not used.

J7-5, CT COM: Make no connection.

J7-6, OSC B: Phase B input oscillator signal. Greater than 10K ohms input impedance, 5.0V rms for full scale voltage, 0.0 volts DC offset, 45 Hz to 5000 Hz input frequency. Use A COM for signal return.

J7-7, A COM: Analog common reference/return.

J7-8, CL B: Make no connection.

J7-9, RPV: External Modulation/Remote Programming Voltage. This input is used in power sources with manual controllers only. The pin normally serves as an external modulation input; a 0.0 to ±10.0 volt DC input provides 0% to 10% amplitude modulation. The pin may optionally be configured as a Remote Programming Voltage input. In this case a 0.0 to ±10.0 volt DC input provides 0 to 100% of full scale output voltage the amplitude control potentiometer must be set fully clockwise. Reference the input to Analog Common, J7 -1.

J7-10, OVR TMP: Over Temperature. This active low open collector output indicates excessive power source heat sink temperature. When active, the power source outputs are disabled.

J7-11, CNF: Make no connection.

J7-12, not used.

J7-13, not used.

J7-14, Not used.

J7-15, Not used.

J7-16, Not used.

J7-17, Not used.

J7-18, Make no connection

J7-19, Not used.

J7-20, Not used.

J7-21, Not used.

J7-22, Not used.

J7-23, OSC C: Phase C input oscillator signal. Greater than 10K ohms input impedance, 5.0V rms for full scale voltage, 0.0 volts DC offset, 45 Hz to 5000 Hz input frequency. Use A COM for signal return.

J7-24, OSC A: Phase A input oscillator signal. Greater than 10K ohms input impedance, 5.0V rms for full scale voltage, 0.0 volts DC offset, 45 Hz to 5000 Hz input frequency. Use A COM for signal return.

J7-25, CL C: Make no connection.

J7-26, CL A: Make no connection.

J7-27, D COM: Digital Common. Use this line as the return for logic signals on the system interface connector.

J7-28, RNG HI: Make no connection.

J7-30, Not used.

J7-31, Not used.

J7-32, Not used.

J7-33, Not used.

J7-34, Not used.

J7-35, Make no connection.

J7-36, REMOTE SHUTDOWN: This 5 volt logic line, when pulled low (to D COM) signals the internal power controller to set the power source output voltages to zero and to open the confidence/output application relays if installed. When the REMOTE SHUTDOWN line is released, the confidence/output application relays are automatically closed, and the output voltages are restored.

CAUTION

Voltages up to 480 VAC are available in certain sections of this power source. This equipment generates potentially lethal voltages.

DEATH

on contact may result if personnel fail to observe safety precautions. Do not touch electronic circuits when power is applied.

SECTION 4

CALIBRATION PROCEDURE

4.1 GENERAL

A routine calibration of the 1503L-M is not required. This procedure should be performed after repair has been made to the unit. Table 4-1 lists the paragraph titles and page numbers for the calibration and test procedures.

Calibration Procedure Listing

PARAGRAPH	PROCEDURE	PAGE
4.3	OPEN SENSE ADJUSTMENT	33
4.4	CURRENT TRANSFORMER ADJUSTMENT	33
4.5	CURRENT LIMIT ADJUSTMENT	34

This calibration procedure assumes that the power source is calibrated at 25°C ambient temperature on the low voltage range. Performance is similar on the high range. Output voltage measurements must be made at the power controller voltage sense point. Otherwise, voltage drops in output wiring may cause inaccurate measurements.

4.2 TEST EQUIPMENT REQUIRED

The following test equipment is required to perform the calibration procedure. It is assumed that the power source is calibrated on the low voltage range.

Digital Voltmeters (DVM), 2: Fluke 8840A
Resistive Load: See LOAD value from Table 4-1
Precision Current Transformer: Pearson 110
Frequency Counter: Philips PM6671
Phasemeter: Krohn-Hite 6500A
Oscilloscope: Kikusui COS6100

RANGE	LOAD (ohms)
135	32.7
156	43.7
67.5	8.2
200	71.9

LOAD PER PHASE

TABLE 4-1

4.3 OPEN SENSE ADJUSTMENT

A Open Sense adjustment potentiometer is provided for each of the three amplifiers in the 1503L. For their location see Figure 4-1. Use the following procedure to adjust the gain of each amplifier.

1. Remove all loads from the power source. Switch the power source on.

2. With the remote sense lines connected, adjust the output voltage to 100.0V rms, 400 Hz.

3. Disconnect the remote sense lines and adjust the associated gain potentiometer until the output voltage is 115.0 ±0.25V rms.

4. Reconnect the External Sense connector, J6.

4.4 CURRENT TRANSFORMER ADJUSTMENT

A current transformer is in series with each of the three amplifiers to sense output current for measurement and protection. The output current of each sense transformer is converted to a voltage by an adjustable burden resistor. Use the following procedure to adjust the burden resistor of an amplifier's current sense transformer. See Figure 4-1 for the location of the burden potentiometers.

1. Wire the output of the phase to be adjusted through a precision current transformer. Monitor the output of the current transformer with a DVM set at 2 volts AC full scale.

2. At the rear panel system interface connector, monitor the current transformer output voltage of the amplifier to be adjusted with a DVM set at 2 volts AC full scale.

   J7-36 CT A
   J7-18 CT B
   J7-35 CT C
   J7-5 CT COM (common)

3. Switch the power source on. Set the output to the lowest voltage range that will deliver 135 volts and 60 Hz. Set the 200 volt range for the EHV option.

4. Apply a 36.5 ohms, 500 watt load to the output of the phase to be adjusted. For the EHV option voltage range (200/400) apply a 72 ohm load. Adjust the output voltage for an output current of 3.5 amps. Adjust the output for 2.5 amps for the EHV option.

5. Allow 30 seconds for the load to stabilize. Adjust the burden potentiometer so that the DVM monitoring the power source current transformer matches the DVM on the precision current transformer within ±0.0004V rms.

4.5 CURRENT LIMIT ADJUSTMENT

Potentiometers on the Current Limit Board set the accuracy of the current limit circuit. The potentiometers are to be set so that the circuit begins to limit the current at 107% of the maximum current for the respective voltage range.

1. Wire the output of phase A through a precision current transformer. Monitor the output of the current transformer with a digital voltmeter.

2. Adjust the output to the low voltage range and the frequency to 60 Hz.

3. Apply the CURRENT LIMIT LOAD value from Table 4-2 to the Phase A output only.

4. Increase the output slowly until the external current transformer indicates the SET VALUE from Table 4-2.

5. On the Current Limit assembly, A11, adjust potentiometer R55 until the OVERLOAD lamp just begins to glow.

6. Repeat steps 1 through 4 for phase B (adjust A11-R62) and phase C (adjust A11-R75).

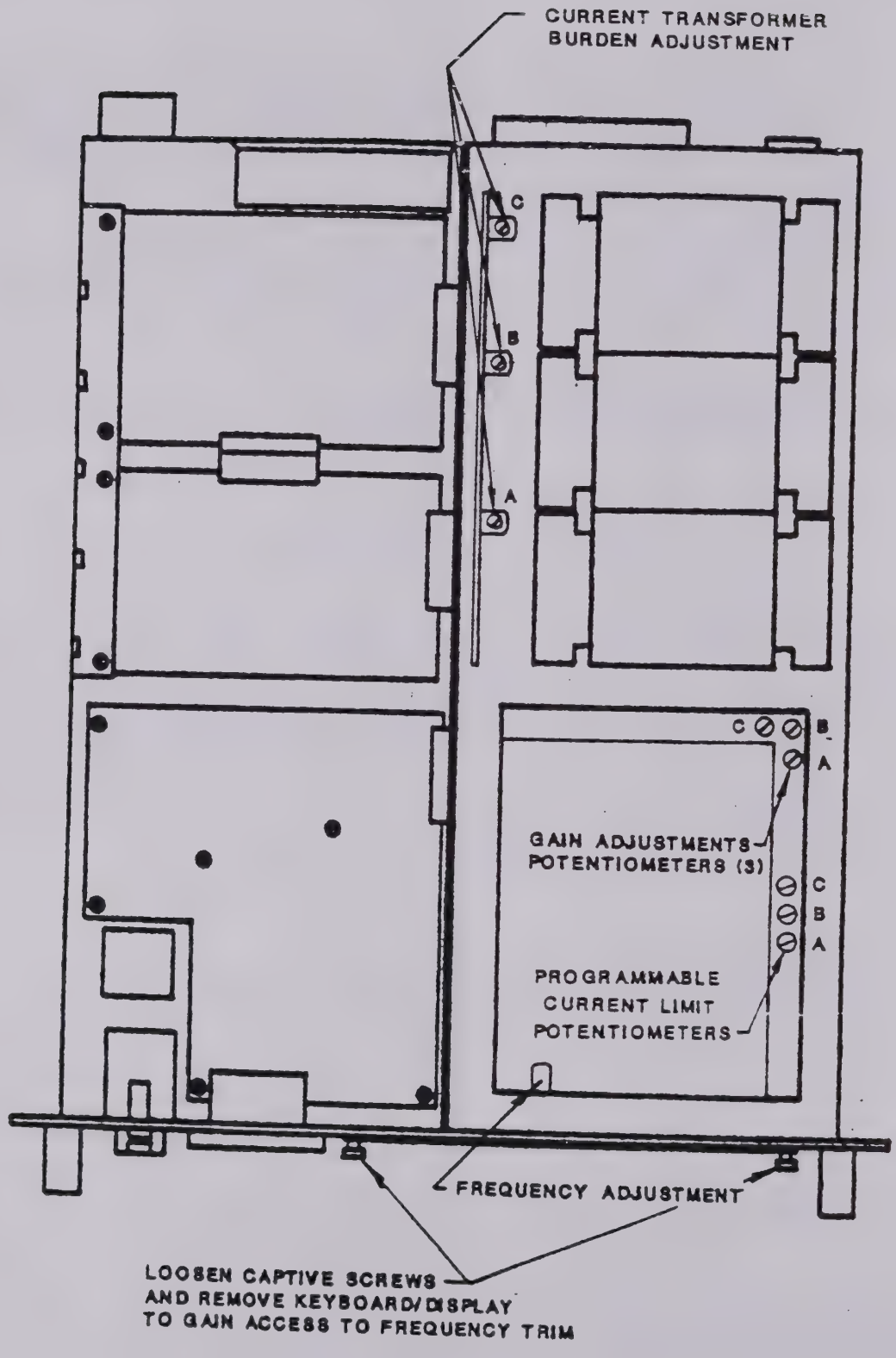


FIGURE 4-1

POWER SOURCE ADJUSTMENTS (TOP COVER REMOVED)

	VA Per Phase	556
135/270 RANGE	LOAD (Ohms)	27
	CURRENT LIMIT:	
	SET VALUE	4.4
	MAX VALUE	5.0
156/312 RANGE	LOAD (Ohms)	31
	CURRENT LIMIT:	
	SET VALUE	3.8
	MAX VALUE	4.1
67.5/135 RANGE	LOAD (Ohms)	13.6
	CURRENT LIMIT:	
	SET VALUE	8.8
	MAX VALUE	9.4
200/400 RANGE	LOAD (Ohms)	40
	CURRENT LIMIT	
	SET VALUE	3.0
	MAX VALUE	3.2

SETUP VALUES

TABLE 4-2

SECTION 5

THEORY OF OPERATION

5.1 GENERAL

An explanation of the circuits within the 1503L is given in this section. Refer to Figure 5-1 for a block diagram of the power source.

5.2 OVERALL DESCRIPTION

Input power at the rear panel is routed through the circuit breaker to the high current rectifier, CR1, and the DC Supply assembly, A4. The various DC supply outputs then go to the Power Mother Board, A3, to be directed to other circuits in the 1503L.

The Power Controller assembly generates the oscillator waveforms and power source control and measurement signals. The Power Controller assembly is connected to the rest of the power source through the Control Mother Board, A10.

The amplifiers, A7, A8, A9, take their DC Supply and Power Controller inputs from the Power Mother board and produce the 500 VA outputs to the Range Relay board, A6.

The Range Relay board directs the amplifier outputs to Output Transformers T1, T2, and T3. The transformer outputs are then connected back to the Range Relay board to configure the correct output voltage range. The final power source outputs are then taken from the Range Relay board.

The PH DE1 and PH DE2 assemblies are installed if the AX option is included in the 1503L. These two boards generate the ϕD/E outputs using signals and power supplies taken from the power mother board, A3. The ϕD/E outputs are routed through the Range Relay board, A6 and then to the rear panel output terminal block, TB-2.

The individual assemblies are explained in more detail in the following paragraphs.

5.3 DC SUPPLY

The DC Supply board, A4, provides the high-voltage main supply and several low voltage power supplies. Figure 5-2 is a simplified schematic of the DC supply. The input circuit breaker and high power rectifier are shown in the diagram for clarity but are not part of the DC Supply board.

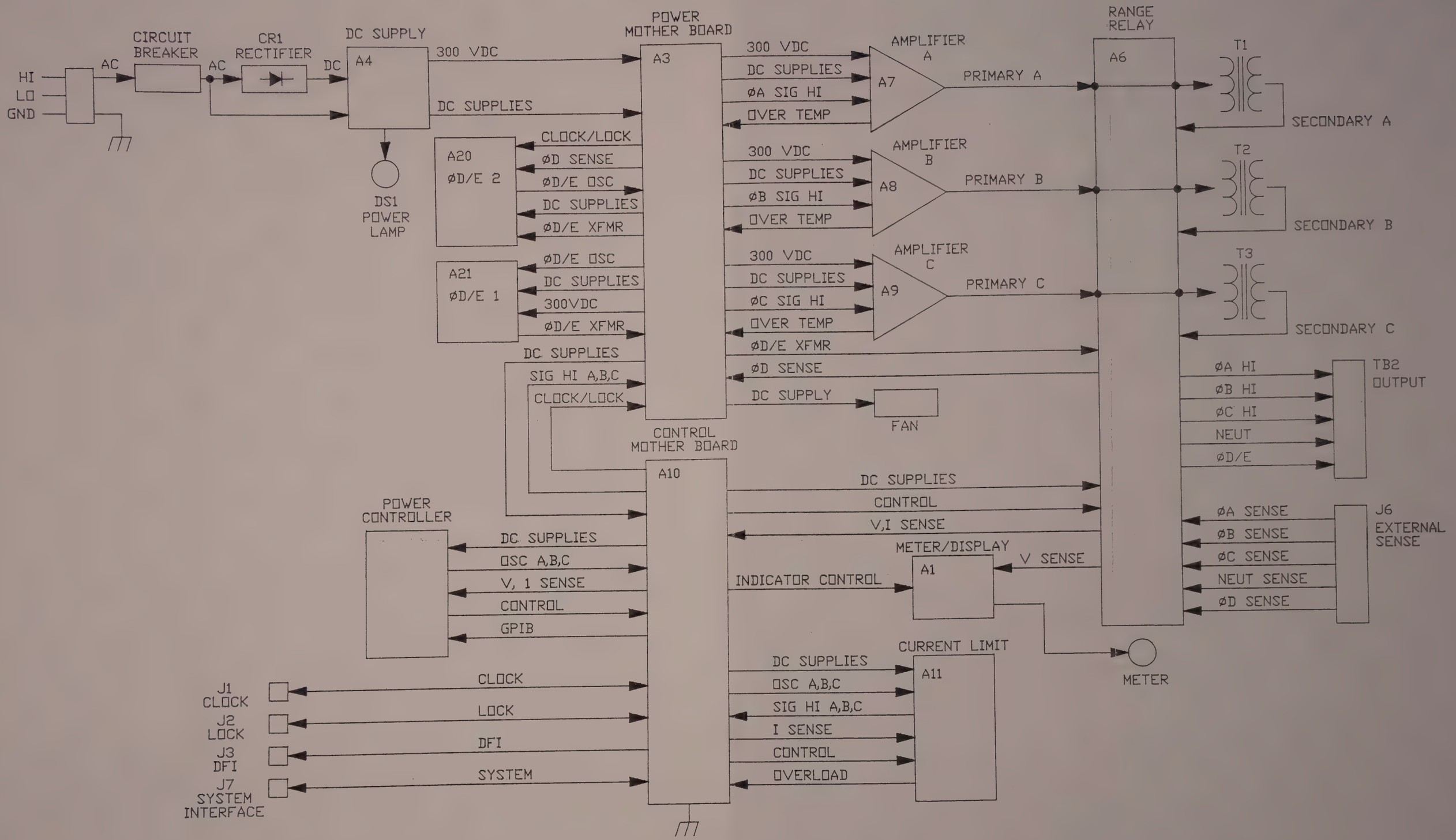


FIGURE 5-1 1503L-3P BLOCK DIAGRAM

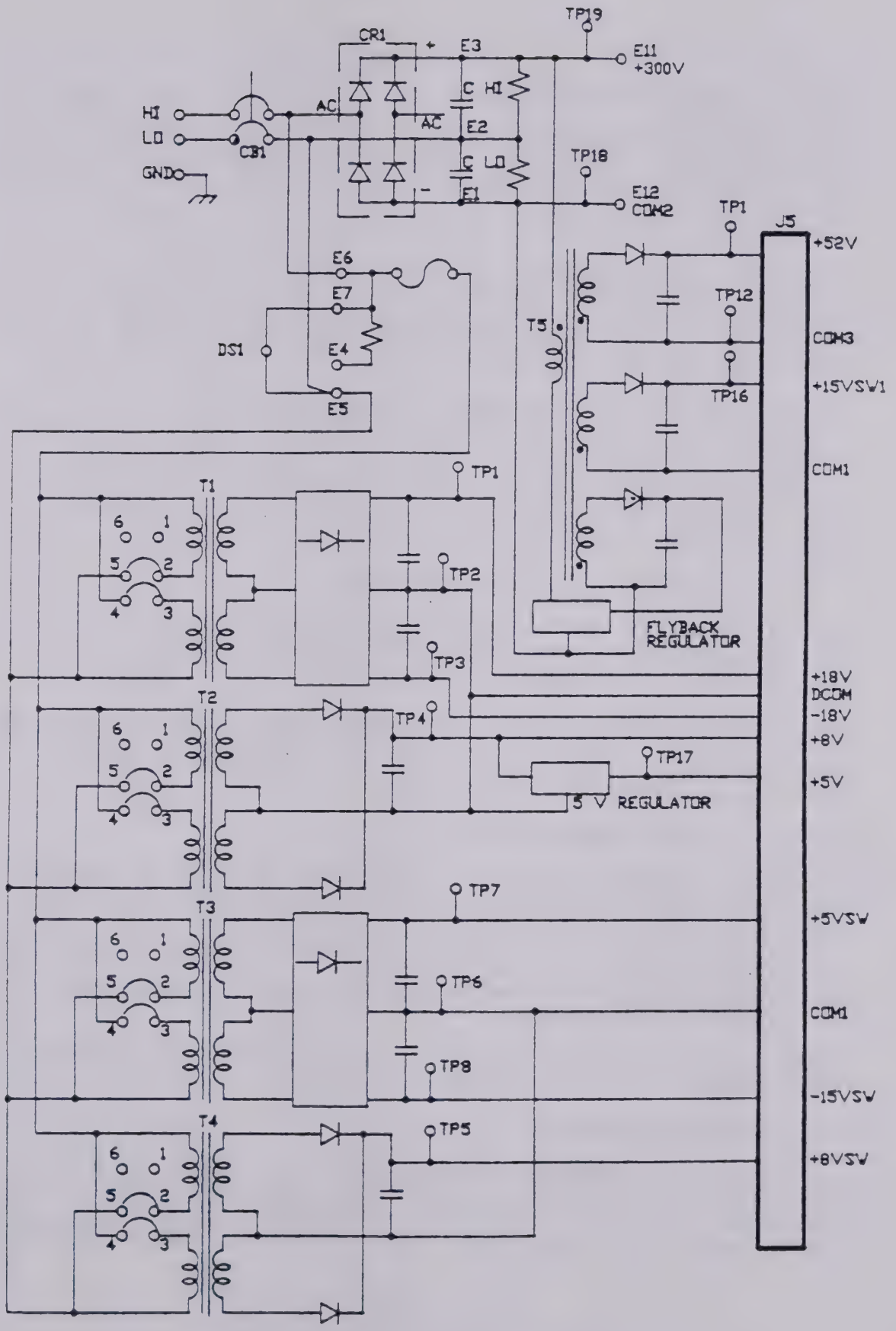


FIGURE 5-2 DC SUPPLY

5.3.1 High Voltage Supply

The high voltage supply provides a 300 volt, 2000 watt source for the three power amplifiers. The input wiring of this supply is configured according to the input voltage range. A voltage doubler is used for the 115 volt range; a full wave rectifier is used for the 230 volt range.

Figure 5-2 shows the high voltage supply wired for the voltage doubler. Capacitors C-HI and C-LO are charged by alternate half cycles of the input voltage. The output voltage at E11 and E12 is the sum of the voltages on the two capacitances and is approximately double the peak voltage of the input sine wave.

To wire the high voltage supply for the 230 volt input range, the connection between CB-1 and E2 is removed and replaced by a connection between CB-1 and the unused AC input of CR-1. The circuit is a simple off-line rectifier. Capacitors C-HI and C-LO are charged in series by each half cycle of the input voltage. The output voltage at E11 and E12 is approximately the peak voltage of the input sine wave.

5.3.2 Flyback Regulated Supplies

Two of the eight low voltage supplies are provided by a 100 KHz flyback regulator. The regulator switches on to draw energy from the 300 volt main supply and charge the primary inductance of T5.

When the regulator switches off, the energy stored in the primary inductance is transferred to the secondaries. The pulse width of the switching waveform is varied as necessary to maintain the secondaries at +15 VDC and +52 VDC.

5.3.3 Low Voltage Supplies

Six low voltage supplies are generated by simple transformer/rectifier/capacitor circuits. The inputs to each transformer are wired according to the input voltage range. Figure 5-2 shows the inputs configured for the 115 volt input. The two primaries of each transformer are wired in parallel. For the 230 volt input range, the transformers are reconfigured using jumpers that put the two primaries in series.

These supplies are not regulated. Their output voltages vary with line voltage and load variations.

5.4 POWER CONTROLLER

A block diagram for the power controller is given in Figure 5-3. The power controller generates the oscillator waveforms for each of the three amplifiers, sets the frequency, amplitude and current limit level, and senses the output voltage to control amplitude.

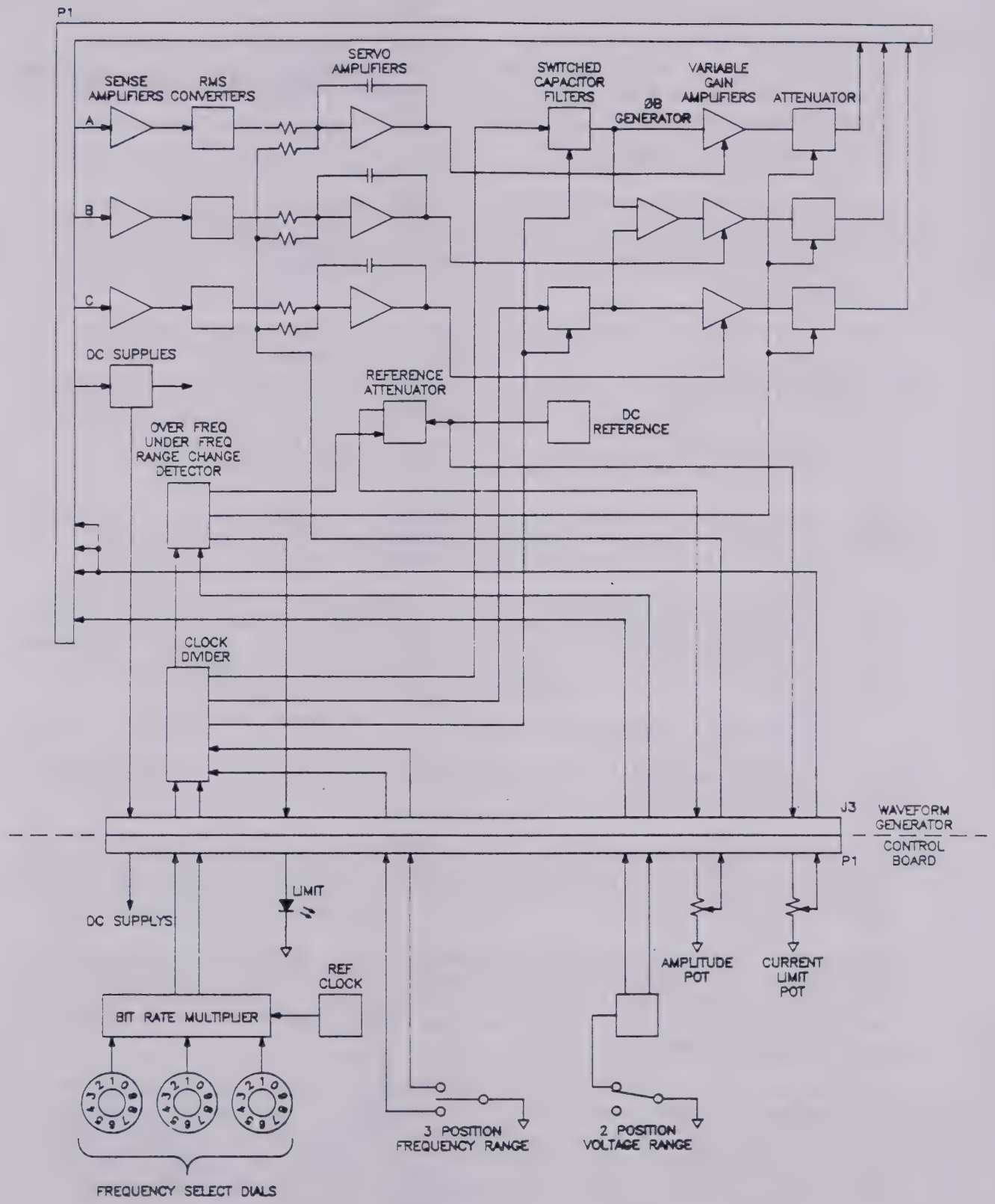


FIGURE 5-3
POWER CONTROLLER 1503L-M

The controller module is made of two printed circuit assemblies that are interconnected by a ribbon cable. An extender board mates the module to the power source.

5.4.1 CONTROL BOARD

The Control board is mounted to a small panel on the front panel of the power source. The small panel holds the Frequency Select dials and Frequency Range switch, the Voltage Amplitude potentiometer, the Voltage Range switch and the programmable Current Limit potentiometer.

A block diagram of the Control board is shown in the lower portion of Figure 5-3. A fixed frequency reference clock (10.24 MHz) drives the bit rate multiplier to control the output frequency of the power source. The output frequency of the bit rate multiplier is equal to frequency select dial setting times the reference frequency divided by 1000. If the dials were set at 500, the bit rate multiplier output frequency would be 5.12 MHz.

The three-position Frequency Range switch signals the Waveform board to divide the bit rate multiplier output frequency by 1, 10 or 100 depending on the desired frequency range.

The Voltage Range switch directly controls the voltage range relays and also sends a short pulse to the Waveform board to signal that the voltage range has changed. The Waveform Generator board uses this pulse to shut off the output voltage while the range relays change state This is to minimize relay contact wear.

5.4.2 WAVEFORM GENERATOR BOARD

A block diagram of the Waveform Generator board is shown in the upper portion of Figure 5-3.

The clock divider divides the bit rate multiplier frequency by 1, 10 or 100 depending on frequency range switch setting. Outputs of clock divider drive the switched capacitor filters and provide a square wave to be filtered into the oscillator output sine wave.

The Over frequency/Under frequency/Range detector monitors the clock output and attenuates the oscillator output if the frequency is outside the specified range of the unit. The detector also momentarily activates the attenuators when the voltage range switch position is changed.

The output of each phase of the power source is applied to a differential sense amplifier, converted to an rms-DC equivalent voltage and compared to a 10 volt DC reference by a servo amplifier. The servo amplifier drives a variable gain amplifier that modulates the oscillator signal. This closed loop system maintains each output at a constant RMS voltage.

5.5 CONTROL MOTHER BOARD

The Control Mother board, A10, makes the necessary signal connections between the various assemblies of the power source. Figure 5-4 is a simplified schematic of the Control Mother board.

The Oscillator CPU connector accepts voltage and current sense signals for measurement, and optically isolated External Sync signals for frequency synchronization. Control and oscillator signals are sent out from this connector.

The Range Relay board connector sends out voltage and current sense signals and accepts relay control signals.

The Power Mother board connector accepts the oscillator signals and sources the DC supplies to rest of the power source.

The Meter/Display board accepts the necessary lines to light the lamps on the front panel.

The External System connector carries all the signals for the rear panel I/O. Note that the Function Strobe signal to this connector is optically isolated.

The Current Limit board connector accepts the current limit, current sense, and oscillator signals. The oscillator signals pass through potentiometers for gain adjustment. Leaving the connector are the modulated oscillator signals.

5.6 POWER MOTHER BOARD

The Power Mother board, A3, provides the high voltage and high current connections for the power amplifiers and DC supply. Figure 5-5 is a simplified schematic of the Power Mother board.

The high voltage supply from the DC Supply board is connected at E1 and E2. The positive supply connection is divided into three lines, one per amplifier. Each of the lines is routed through a fuse and a filter inductor.

The DC Supply board plugs into the Power Mother board. It provides DC power to each of the amplifier control boards as well as the rest of the power source.

The Control Mother board connector accepts the DC supply lines and provides oscillator signals to each amplifier.

Each power amplifier module plugs into the Power Mother board through two connectors. One connector is dedicated to the high current supply and output wiring. The other connector provides the DC supplies and oscillator signals to the amplifier controller. Output power from each amplifier is directed to the Relay board through standoffs on the Power Mother board.

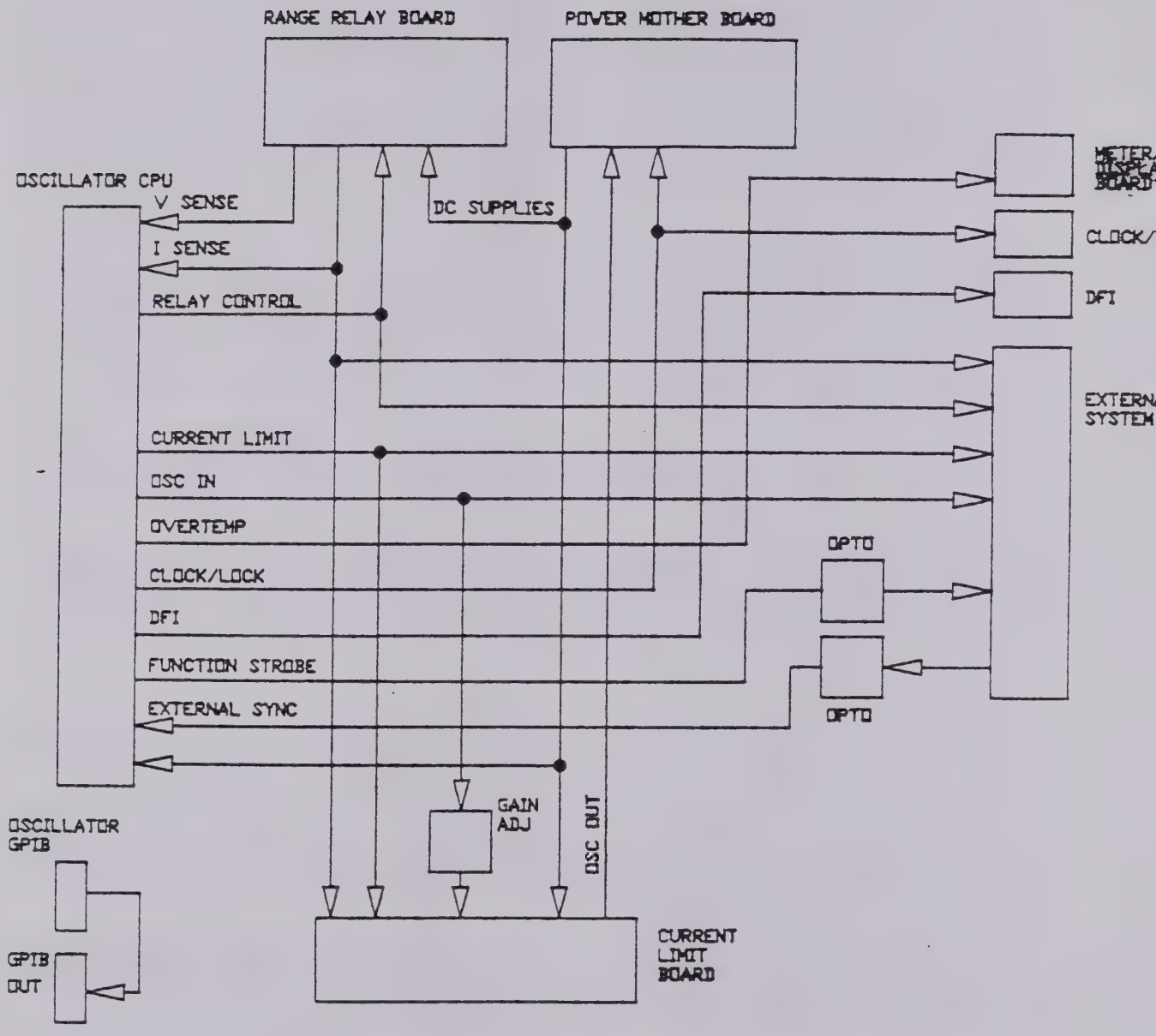


FIGURE 5-4 CONTROL MOTHER BOARD

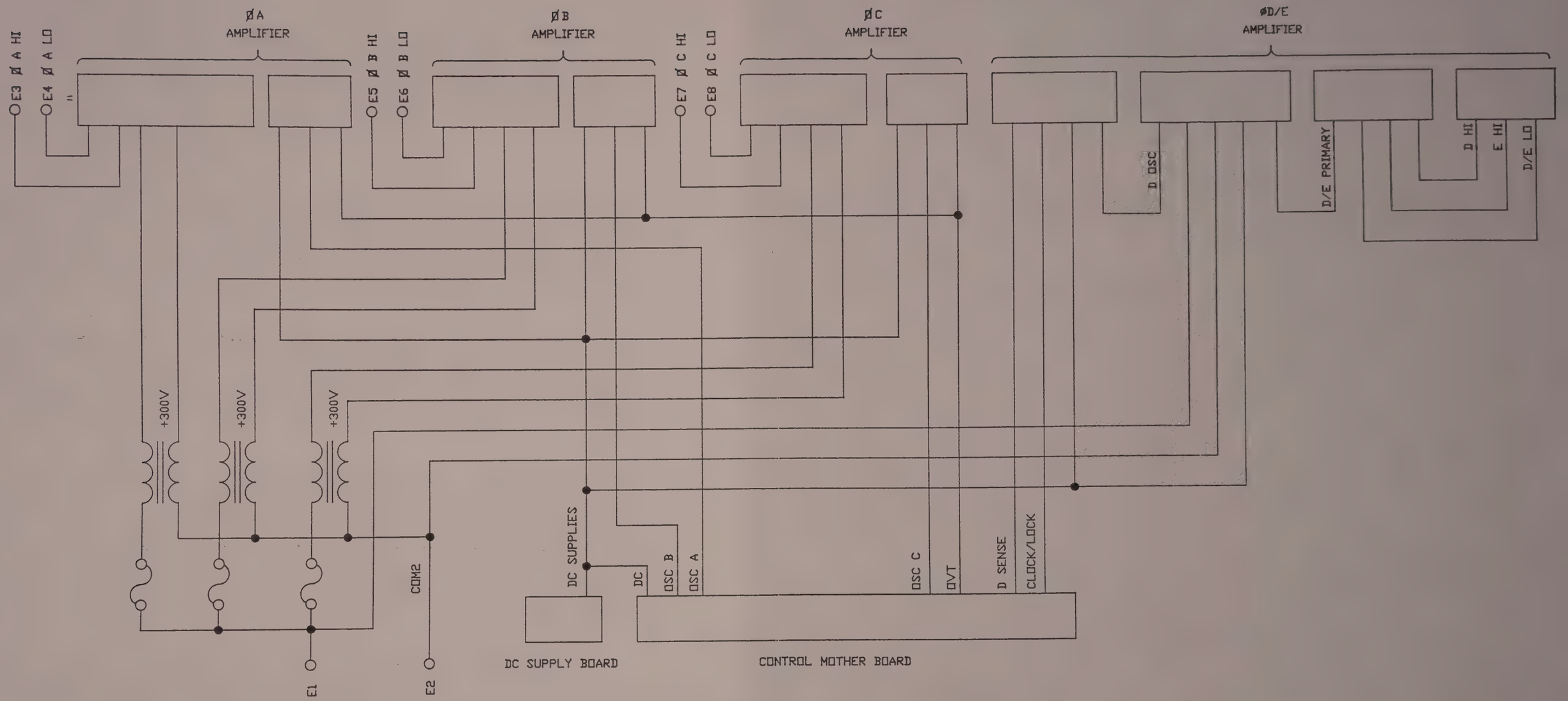


FIGURE 5-5 POWER MOTHER BOARD

5.7 POWER AMPLIFIERS

There are three identical power amplifiers in the power source, A7, A8, and A9, one per phase. Each amplifier consists of a control board, a high power board and the power semiconductors. These components are mounted to a heat sink to form a Power Amplifier module. A description of the Power Amplifier module is given in the following paragraphs. Figure 5-6 shows a simplified schematic of the amplifier.

5.7.1 HIGH POWER BOARD

The high efficiency of the 1503L power source is attained because the amplifiers use switching technology. In the common, low efficiency class AB amplifier, transistors are used as variable resistance series pass elements. Transistors in class AB amplifiers act as voltage dividers between the amplifier power supply and its load. As the load draws more current, the transistors dissipate more power.

In the high efficiency switching amplifier, MOSFETs are used as switches; they are either turned on completely or turned off completely. This means that the transistors are always in a low power dissipation state. When the MOSFETs are on, they are passing high currents but with minimum voltage drop; when the MOSFETs are off, a high voltage is dropped across them but only leakage currents flow.

The L series amplifier is configured in the full bridge topology. In Figure 5-6 it is seen that the output is connected so as to bridge pairs of the switching transistors. The transistors are turned on and off as diagonal pairs; either A and B are turned on with C and D off, or C and D are turned on with A and B off. Switching the MOSFETs as diagonal pairs allows an alternating current to be generated from a single DC supply. When transistors A and B are on, OUT HI is pulled toward +300 V, OUT LO is pulled to COM 2 return. When transistors C and D are on, the situation is reversed; OUT LO is pulled to +300 V and OUT HI is pulled to COM 2.

A diode is connected in series with each of the switching transistors to block reverse current flow in the transistors. A diode in parallel with each series transistor-diode pair shunts reverse flowing currents around the pair.

Inductor-capacitor filters smooth the 200 Khz pulse waveform to pass only low frequency components to the output. This filtered output is sensed and sent to the Control board.

A high frequency current transformer senses the 200 Khz current pulses drawn by the amplifier. The current transformer output is used by the Control board to detect over-current conditions.

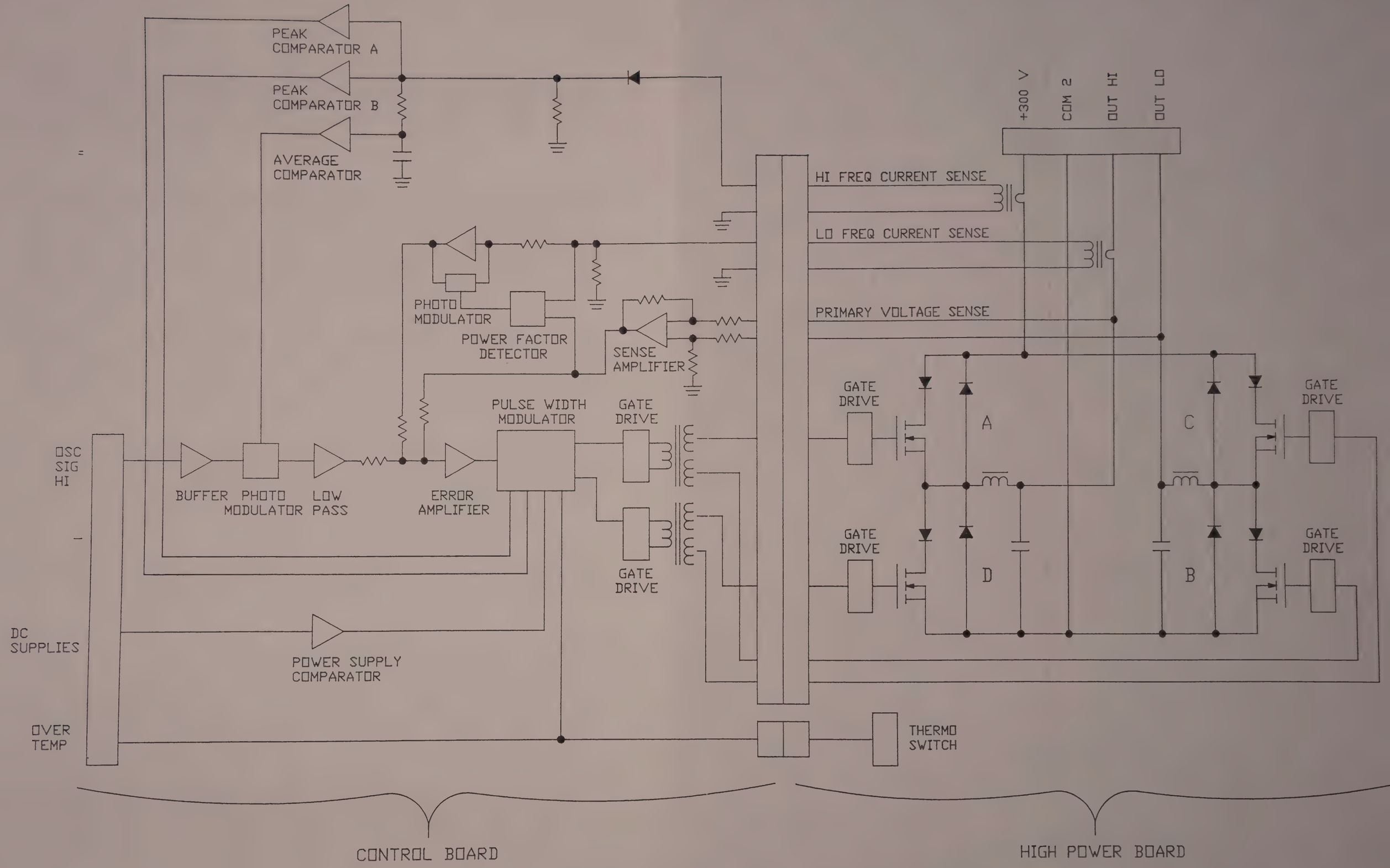


FIGURE 5-6 POWER AMPLIFIER

A low frequency current transformer senses the smoothed amplifier output current. The secondary voltage of this transformer is sent to the error amplifier on the Control board. This voltage boosts the amplifier output voltage slightly to make up for losses in the system as load current increases.

5.7.2 CONTROL BOARD

The main function of the Control board is to generate the gate drive signals for the High Power board. Other functions include overcurrent, overtemperature and power supply fault detection.

In Figure 5-6 the input OSC SIG HI signal enters the board on the left. This waveform is buffered, sent through a photomodulator and low pass filter. This filtered waveform is then sent to an error amplifier which drives the pulse-width modulator.

The pulse-width modulator samples the error amplifier's output to generate a 200 Khz, variable duty cycle pulse waveform. The amplifier output voltage is proportional to the duty cycle minus the complement of the duty cycle. Therefore, positive portions of the input signal cause duty cycles greater the 50%. Negative portions of the input signal cause duty cycles less than 50%. No input signal (zero volts) causes a duty cycle of exactly 50%.

The output of the pulse-width modulator drives two gate drive circuits. The output of each gate drive circuit is transformer coupled to the High Power board. The two secondaries of each transformer drive the two switches of a diagonal MOSFET pair. That is, the two secondaries of one gate drive transformer drive MOSFETs A and B; the two secondaries of the other transformer drive MOSFETs C and D.

The output voltage of the power amplifier is sensed by a differential amplifier which removes the high common mode voltage. The differential amplifier output is then fed to the error amplifier. This closes the feedback loop around the pulse-width modulator and full bridge amplifier.

The power amplifier output current is sensed by a low frequency current transformer on the High Power board. The sensed current is converted to a voltage, amplified, and sent to the error amplifier through an adjustment potentiometer. As load currents increase so will output voltage. This is to make up for the losses of the output transformer. The power factor of the load is detected and used to modify the amount of current feedback. Low power factor loads decrease the current feedback in order to increase amplifier stability.

The power amplifier switch current is sensed by a high frequency current transformer on the High Power board. The sensed current is converted to a voltage which is used for current fault protection. Three comparators use this current sense signal.

The first comparator is a peak current limiter. It acts to turn off the MOSFET switches on a pulse by pulse basis if the current crest factor goes beyond 2.5 of the maximum rms current.

A second peak comparator is set for a higher current than the first. It temporarily shuts down the pulse-width modulator so that no switch may turn on. This comparator protects against negative power factor loads.

The third comparator is an average current limiter. Its threshold is set lower than those of the previous two, but because an RC network is averaging the current sense signal, it acts more slowly than the peak current limiters. When an average current limit fault is detected, the comparator decreases drive to the photomodulator in series with the oscillator input signal. This causes the output waveform to be clipped.

A power supply comparator senses +15 VSW1 and shuts off the pulse-width modulator if the voltage is less than 11 volts DC. This is to protect the amplifier when power to the 1503L is switched on or off.

A thermoswitch mounted to the power amplifier heatsink is tripped at a heatsink temperature of approximately 100 degrees C. If activated, the pulse-width modulator is disabled until the heatsink cools down.

5.8 RANGE RELAY BOARD

The Range Relay board, A6, holds components to set the output voltage range, sense the output voltages and currents, and disconnect the outputs from the rear panel terminal block. Figure 5-7 is a simplified schematic of the Range Relay board.

The circuits that implement these functions are similar for Phases A, B, and C, so they are only shown once, for Phase A, in Figure 5-7.

The output of the Phase A amplifier is connected from the Power Mother board to E1 and E2 on the Range Relay board and then to the output transformer primary via a connector on this board. The secondaries of the output transformer return to the Range Relay board on the same connector.

The secondaries are rated for 135 volts, 250 VA each. A double pole, double throw relay connects the secondaries in parallel for 135 volt operation or in series for 270 volt operation.

The HI output passes through the single turn primary of a current transformer. The secondary current of this transformer is converted to a voltage by a variable resistor. This voltage is used for output current and power measurement.

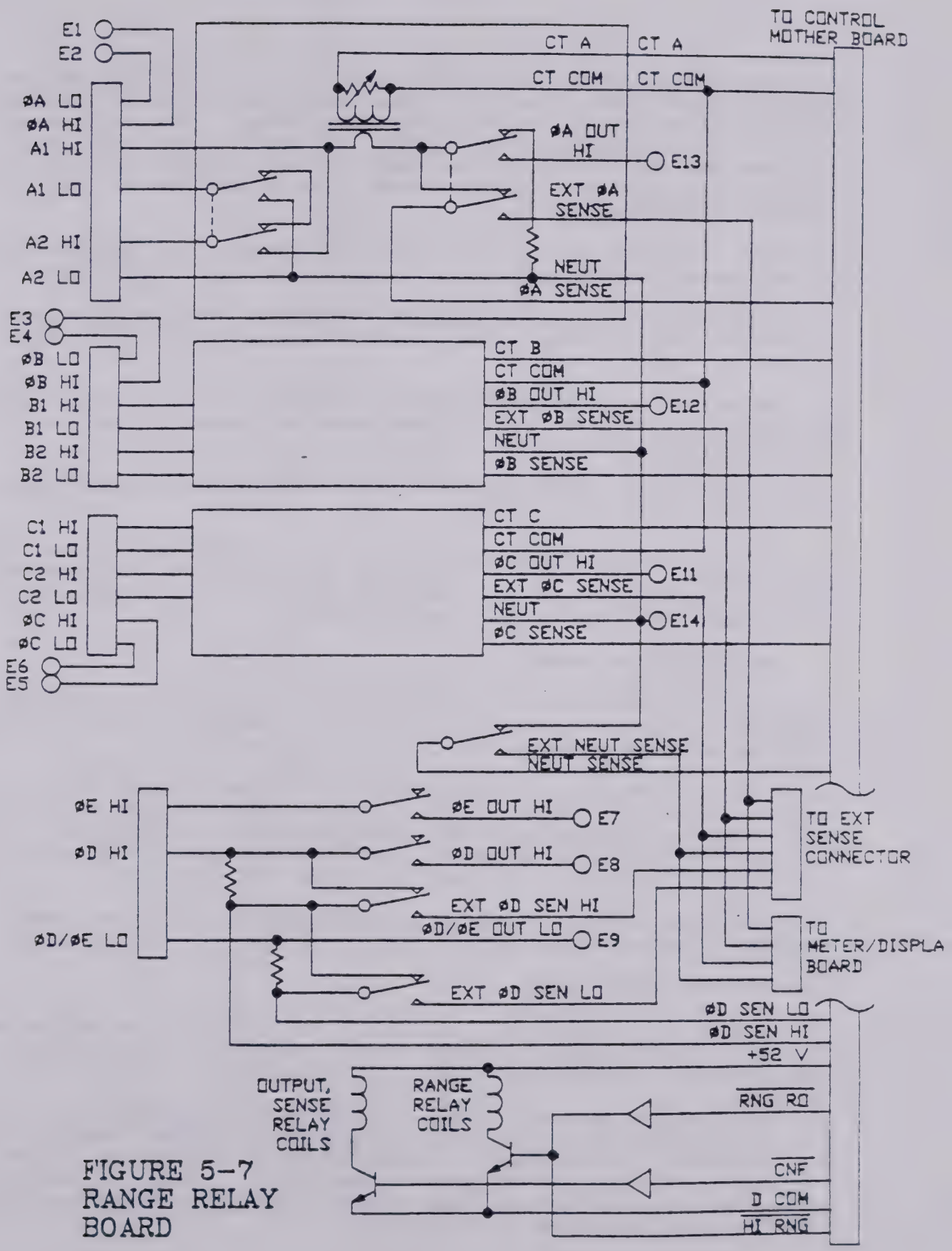


FIGURE 5-7
RANGE RELAY
BOARD

Two relays in each output circuit switch the output HIGH and the external sense line. The first relay switches the output between an internal mode and the output terminal block. The other relay switches the external sense point between an internal sense position and the rear panel terminal block. An additional relay switches the external neutral sense between an internal and an external sense point.

Circuits for range switching, output switching, and voltage and current sensing for Phases B and C operate in a similar manner.

If the AX option is installed, output switching relays are included for Phases D and E, and a remote sense relay is installed for Phase D.

The RNG R0 logic signal controls the range selection relays. When the signal is low, the high voltage range is chosen; when the RNG R0 signal is high, the low voltage range is chosen.

A buffered RNG R0 line, HI RNG, is used to drive the HIGH RANGE lamp on the 1503L front panel.

Output switch and remote sense relays are controlled by the CNF logic signal. When CNF is low, the output relays are open and internal sensing is active. When CNF is high, the output relays are closed, and external sensing is active.

5.9 METER/DISPLAY BOARD

A simplified schematic of the Meter/Display board, A1, is given in Figure 5-8. The board holds the front panel indicator lamps and the phase selector switch for the front panel meter.

The HIGH RANGE function is indicated by an LED when the HI RNG line is pulled low. The OVERTEMP LED is lit when the OVT line is pulled low; this also pulls the OVTEMP line low, an indicator signal to the rest of the power source. The OVERLOAD LED is lit when a programmable current limit fault pulls the OVL line low.

A single pole, triple throw switch selects the Phase A or Phase B or Phase C output to drive the front panel meter.

5.10 CURRENT LIMIT BOARD

The Current Limit board, A11, modulates the oscillator waveforms to provide a programmable current limit function. A simplified schematic of this board is given in Figure 5-9.

The OSC A signal passes through a photomodulator before going to the power amplifier. The modulated signal is called PHASE A SIG HI. Normally the modulator is biased fully on and passes the OSC A signal to PHASE A SIG HI without changing it. During a programmable current limit fault, the modulator bias is reduced and the PHASE A SIG HI waveform is clipped.

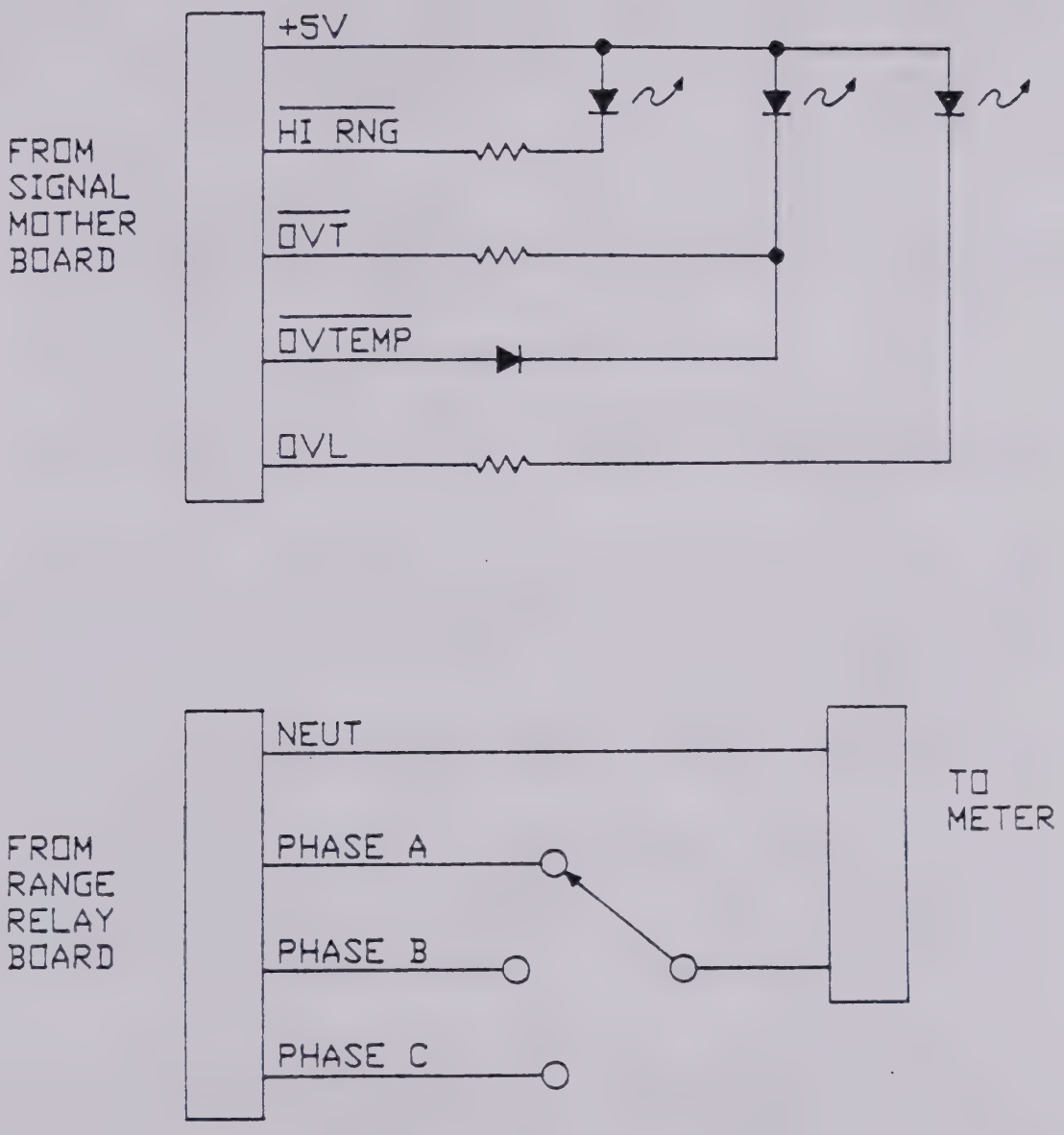


FIGURE 5-8 METER/DISPLAY BOARD

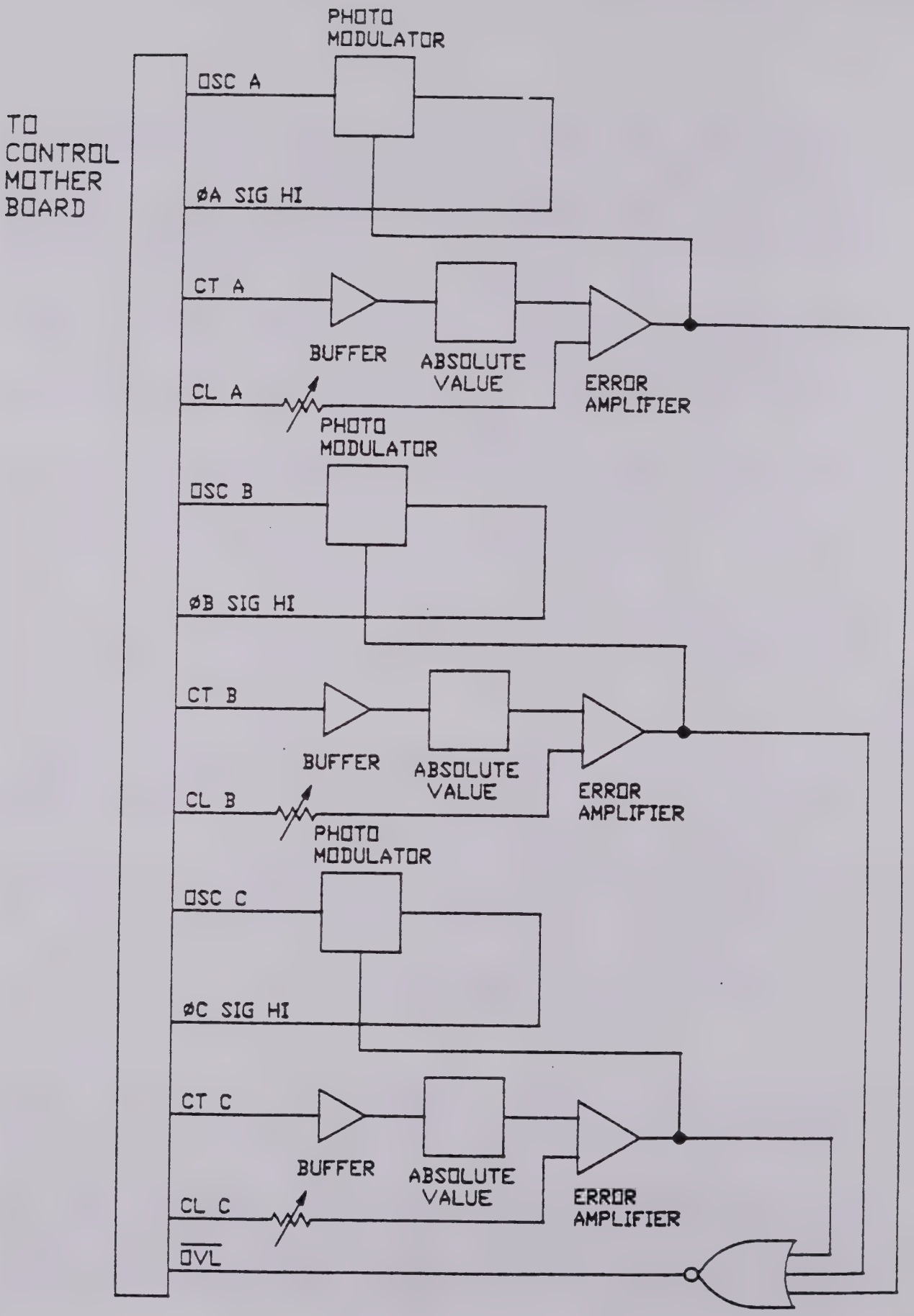


FIGURE 5-9 CURRENT LIMIT BOARD

An error amplifier controls the photomodulator. The inputs to this error amplifier are a programmable DC reference from the power controller and an averaged absolute value of the output current sense signal. The error amplifier adjusts the bias to the photomodulator in an attempt to maintain a difference of zero between the sensed output current and the programmed DC reference.

This error amplifier and photomodulator circuit is repeated for Phases B and C.

The outputs of each error amplifier are connected to the inputs of a NOR logic gate. When any error amplifier output goes high, the NOR output goes low pulling the OVL signal low. This illuminates the OVERLOAD LED on the front panel.

5.11 AX OPTION (Auxiliary Outputs)

The AX Option provides two additional outputs to the 1503L: a 26-volt, 3-amp Phase D output, and a 5-volt, 5-amp Phase E output. The option consists of two P.C. boards as well as cables and relays.

The first P.C. board, PH DE 1, is a switching amplifier similar to the Phase, A, B, C amplifiers. The theory of operation is the same as described in Section 5.7 except that there is no LO FREQ current sense circuit or thermoswitch circuit and all circuits are included on one P.C. board. See Figure 5-10 for a simplified schematic.

The second P.C. board, PH DE 2, includes a sine wave generator, an error amplifier and an output transformer. A simplified schematic is given in Figure 5-11.

The CLOCK line drives the sine wave generator. CLOCK is a logic signal switching at 1024 times the output frequency. A divider circuit generates the output frequency. The LOCK signal is a logic signal switching at the output frequency. It is used to load variable divider presets to allow for phase adjustment of the oscillator output.

The output frequency logic signal from the divider is applied to two cascaded switched capacitor filters. These 4-pole filters are clocked at 64 times the output frequency and attenuate overtones of the logic signal to leave a low distortion sine wave oscillator output.

The Phase D HI and LO outputs are applied to a differential sense amplifier and then converted to DC by a true-rms-converter. This DC sense signal is compared to a DC reference by an integrating error amplifier. The output of the error amplifier controls a modulator so that the Phase D output is maintained at 26 volts rms.

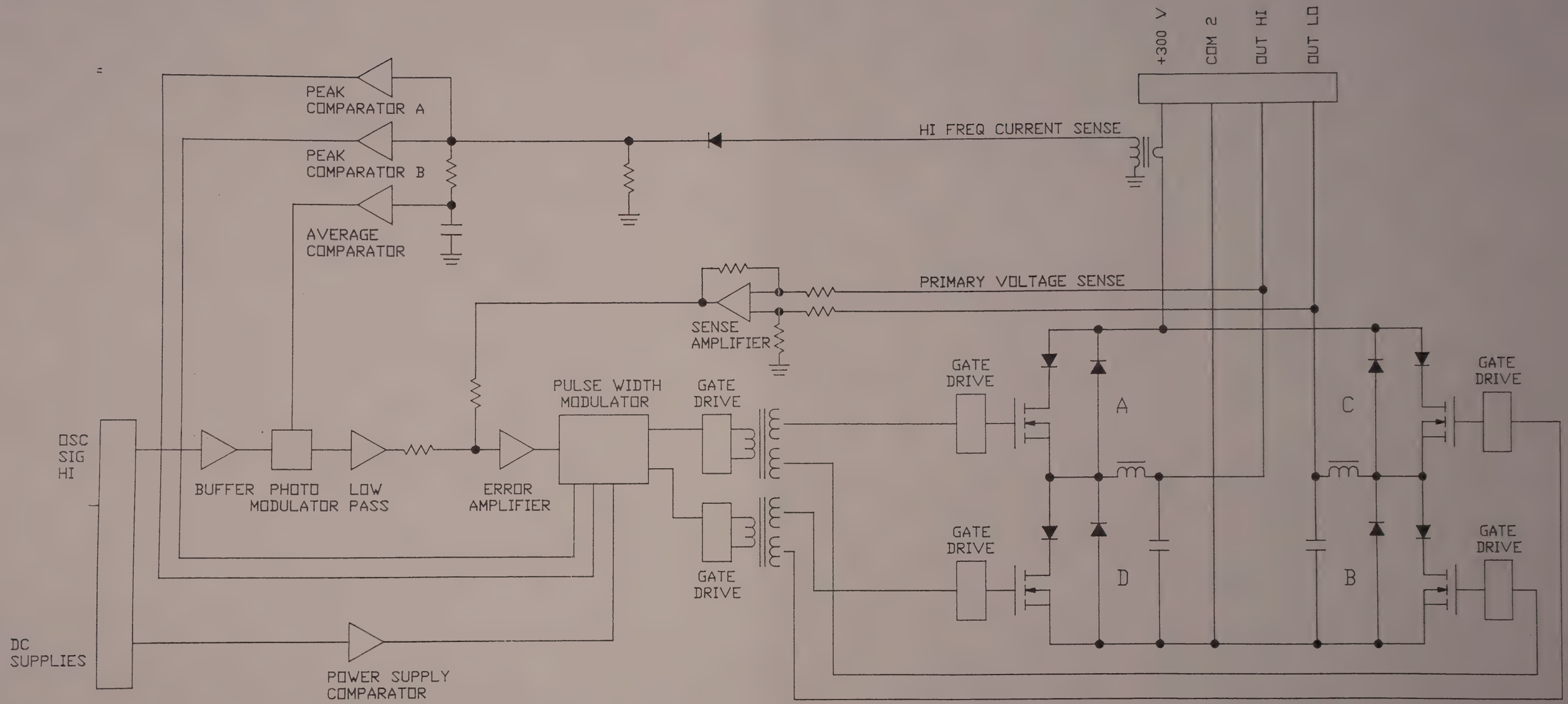


FIGURE 5-10 SWITCHING AMP ØDE1

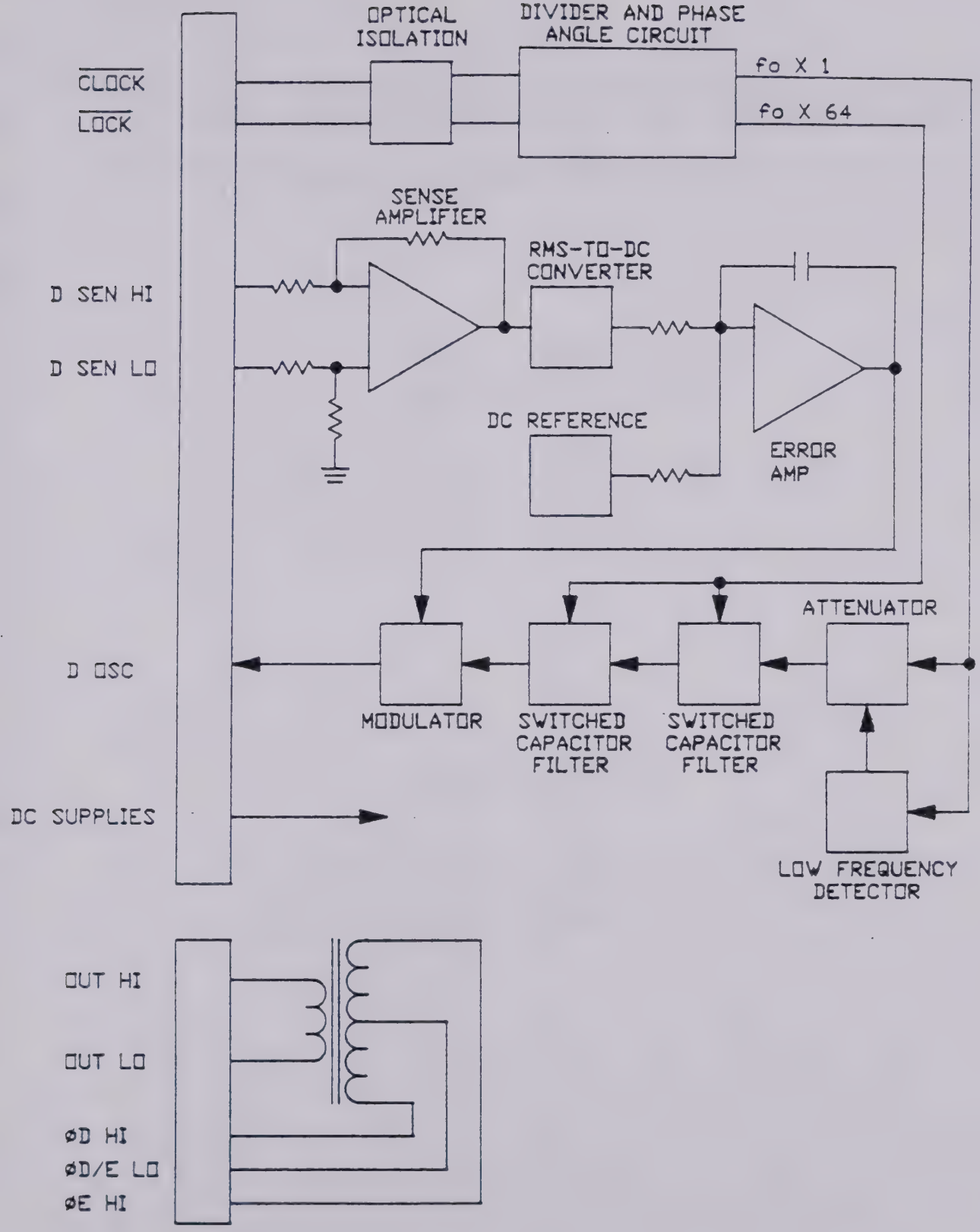


FIGURE 5-11 SWITCHING AMP øDE2

The Phase DE 2 board also holds an output transformer that converts the 100 volt primary to a 26 volt and a 5 volt secondary.

A low frequency detector switches off the output for frequencies below 300 Hz to prevent output transformer saturation.

CAUTION

Voltages up to 480 VAC are available in certain sections of this power source. This equipment generates potentially lethal voltages.

DEATH

on contact may result if personnel fail to observe safety precautions. Do not touch electronic circuits when power is applied.

SECTION 6

MAINTENANCE AND TROUBLESHOOTING

6.1 GENERAL

This section describes the suggested maintenance and troubleshooting procedures for the 1503L. Table 6-1 lists the paragraph titles and page numbers for the Troubleshooting section.

TABLE 6-1

PARAGRAPH	PROBLEM	PAGE
6.3.1	Poor Voltage Accuracy/Regulation	58
6.3.2	Overtemperature Lamp On	58
6.3.3	Overload Lamp On	59
6.3.4	Power Source Output Distorted	59
6.3.5	No Power Source Output	60

6.2 MAINTENANCE

The California Instruments 1503L is a solid state unit and should require a minimum of maintenance. However, the power source is forced-air cooled and will accumulate dust with time. Dust on the power source ventilation holes should be removed as necessary.

6.3 TROUBLESHOOTING

If the 1503L power source does not appear to function normally, use this section to isolate the problem. If the problem cannot be found using these steps, consult the factory.

6.3.1 POOR VOLTAGE ACCURACY/REGULATION

If the power source exhibits poor programmed voltage accuracy, poor line regulation, or poor load regulation, the following item may be at fault:

1. Voltage sense lines are disconnected or incorrectly connected.

   SOLUTION: Connect voltage sense lines. See Section 2.6.2.

6.3.2 OVERTEMPERATURE LAMP ON

If the power source OVERTEMP lamp is on, the following items may be at fault:

1. Ambient temperature is too high.

   SOLUTION: Operate power source between 0 and 50°C.

2. Fan or ventilation holes are blocked.

SOLUTION: Remove obstructions.

3. Fan not working.

SOLUTION: Replace fan. Consult factory.

6.3.3 OVERLOAD LAMP ON

The OVERLOAD lamp comes on when the output load current has exceeded the programmable current limit set level. If the power source OVERLOAD lamp is on, the following items may be at fault:

1. The output is overloaded.

SOLUTION: Remove the overload.

2. The programmable current limit level is set too low for the load being driven.

SOLUTION: Compute and reprogram the correct programmable current limit level.

6.3.4 POWER SOURCE OUTPUT DISTORTED

If the power source output is distorted from a sine waveform, the following items may be at fault:

1. The power source output is overloaded.

SOLUTION: Remove overload. Observe power source capabilities. See Section 1.

2. The output is being clipped by the programmable current limiter.

SOLUTION: Programmable current limit level is set too low. Compute and reprogram the correct programmable current limit level.

3. Power source input is similarly distorted. Check the oscillator signals with oscilloscope at the system interface connector:

J7-24 Oscillator Phase A
J7-6 Oscillator Phase B
J7-23 Oscillator Phase C
J7-7 Oscillator common/return

SOLUTION: If the power source is not configured with an internal power controller, the oscillator signals are being provided externally on pins listed above. Provide an undistorted input.

SOLUTION: If the power source is configured with an internal power controller, the power controller has failed. Replace the power controller. See Section 6.4.1

6.3.5 NO POWER SOURCE OUTPUT

If power source provides no output at the rear panel terminal block TB-2, the following items may be at fault:

1. The output is overloaded.

   SOLUTION: Remove overload. Observe power source capabilities. See Section 1.

2 The power source has detected an overtemperature condition.

   SOLUTION: See Section 6.3.2.

3. The confidence/output application relays are open.

   SOLUTION: The CNF line, J7-11 on the rear panel, must be pulled high. This line is pulled up internally; remove any connection that would pull the line down to D COM.

4. The power source has no input signal. Check the oscillator signals with oscilloscope at the system interface connector:

   J7-24 Oscillator Phase A
   J7-6 Oscillator Phase B
   J7-23 Oscillator Phase C
   J7-7 Oscillator common/return

   For full scale output these signals must be at 5 volts rms.

   SOLUTION: If the power source has no internal power controller, these signals must be provided on rear panel system interface connector, J7. Provide correct signals.

   SOLUTION: If the power source is configured with an internal power controller, verify that outputs are set correctly. If the power controller is correctly set but is not generating oscillator signals, the controller may have failed. Replace the power controller. See Section 6.4.1.

7. One of the internal DC supplies has failed.

   SOLUTION: See Section 6.4.3.

6.4 MODULE TESTING AND REPLACEMENT

6.4.1 POWER CONTROLLER REMOVAL/REPLACEMENT

If a fault has been found that requires the replacement of the power controller module (Oscillator Module Assembly 4007-407), use the following procedure. See Figure 6-1.

1. Disconnect line power at the 1503L input TB-1.
2. Remove the power source top cover.
3. Remove the #6 screw on the bottom of the chassis near the front panel.
4. Loosen the three #6 screws that hold the printed circuit board in place.
5. Lift the printed circuit board from the chassis unplugging it from the small Oscillator Extender assembly (4008-707).
6. Unplug the ribbon cable between the printed circuit board and the controller panel.
7. Remove the controller panel by loosening its two captive screws.
8. Remove the Oscillator Extender assembly (4008-707).
9. The module is now removed. The complete module consists of the oscillator extender, the printed circuit board, and the controller panel.
10. The module may be replaced using the reverse of these steps.

6.4.2 AMPLIFIER REMOVAL/REPLACEMENT

If a fault has been found that requires the replacement of an amplifier module (Amplifier Assembly 4008-410), use the following procedure. See Figure 6-2.

There are three identical amplifiers in the power source, one for each phase. Phase A is the top amplifier, Phase B is the middle amplifier, and Phase C is the bottom amplifier.

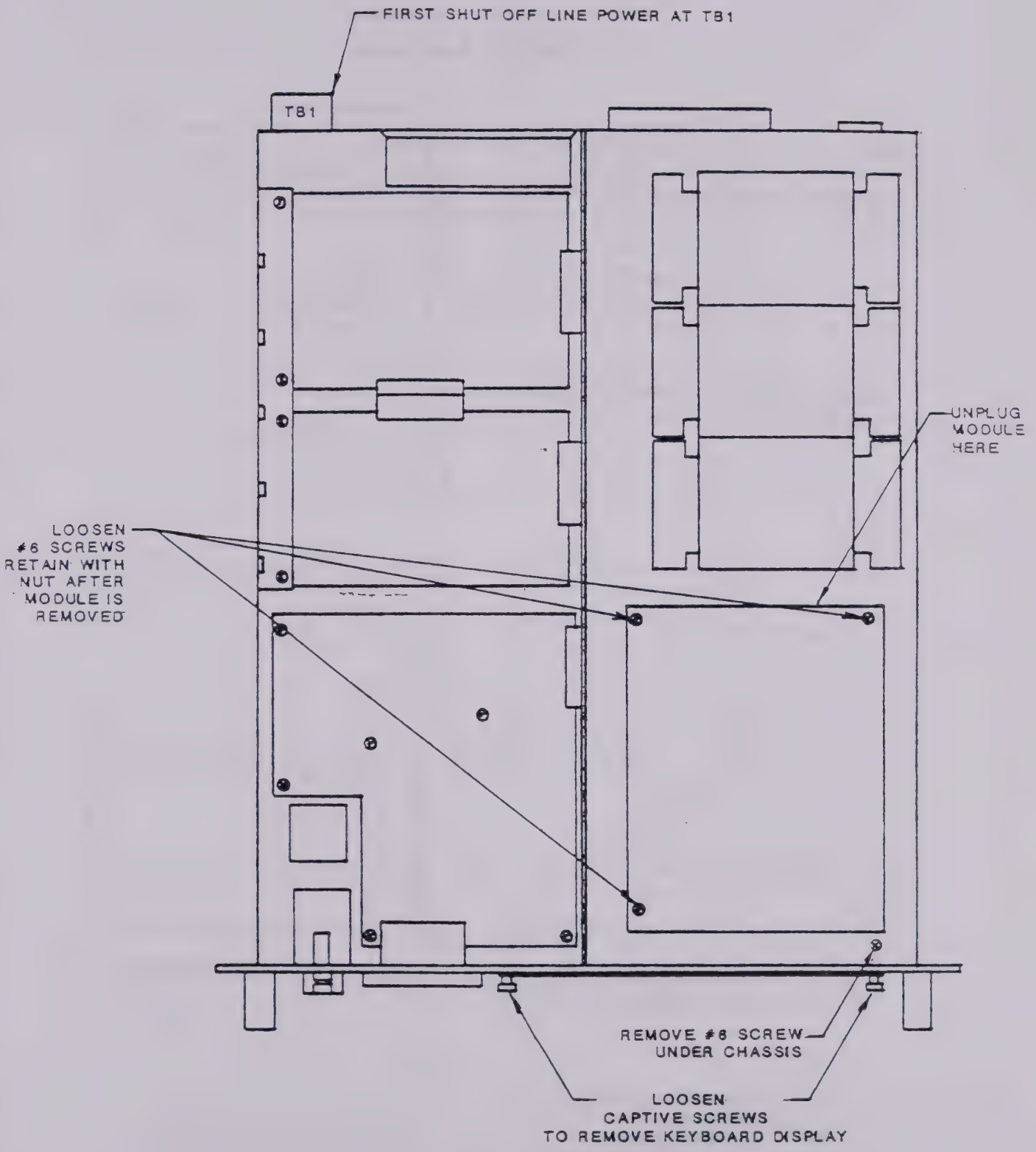

FIRST SHUT OFF LINE POWER AT TB1
TB1
UNPLUG MODULE HERE
LOOSEN #6 SCREWS RETAIN WITH NUT AFTER MODULE IS REMOVED
REMOVE #6 SCREW UNDER CHASSIS
LOOSEN CAPTIVE SCREWS TO REMOVE KEYBOARD DISPLAY

FIGURE 6-1

PROGRAMMABLE POWER CONTROLLER REMOVAL

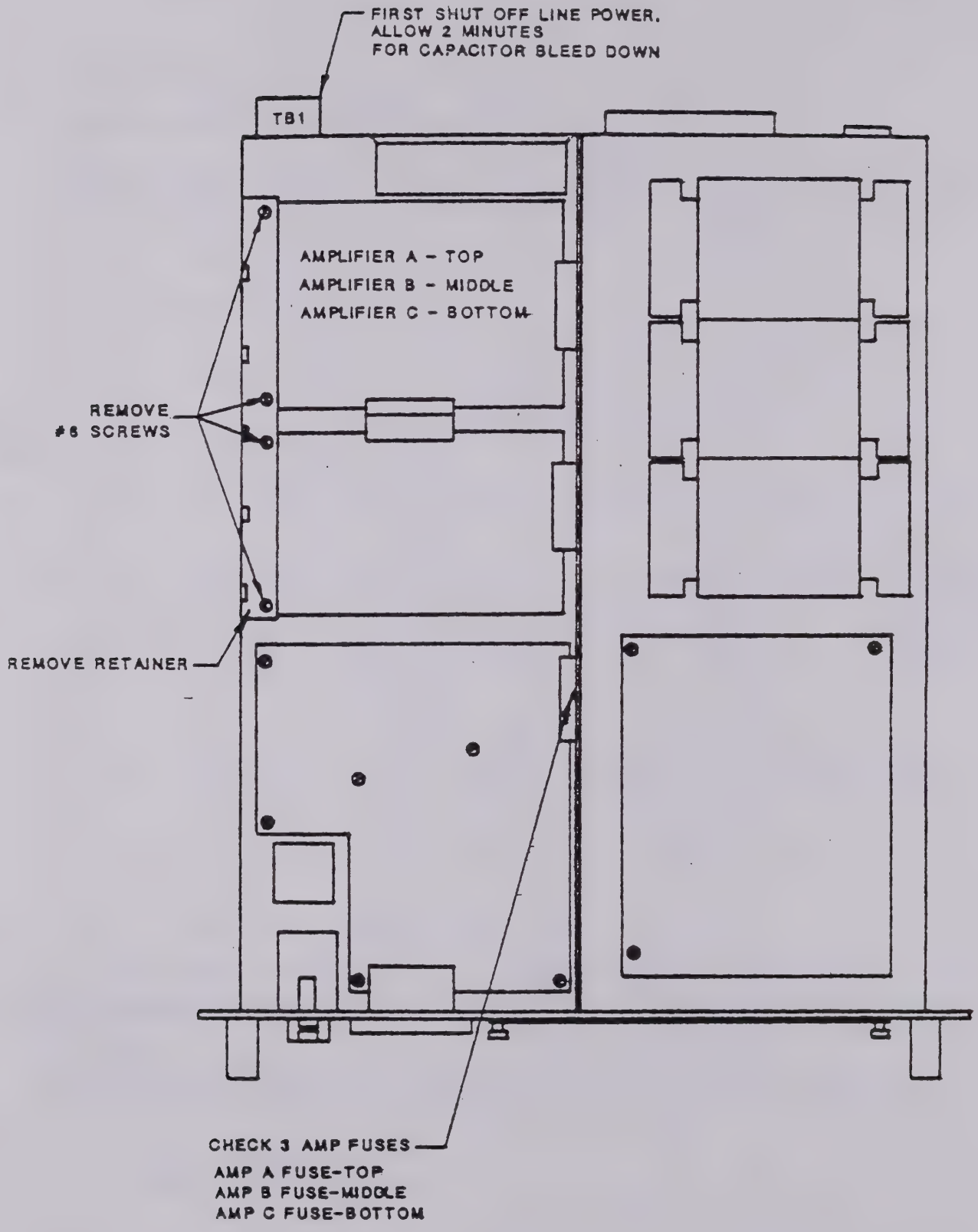


FIGURE 6-2

AMPLIFIER REMOVAL

WARNING

Filter capacitors on the amplifier assemblies may be charged to 360 volts DC. These capacitors are bled down by resistors on the DC Supply module. Do not attempt to remove an amplifier until it has been allowed to discharge for at least two minutes.

1. Disconnect line power at the 1503L input TB-1.

2. Remove the power source top cover.

3. Remove the four #6 screws that hold the insulating retainer in place. Remove the retainer.

4. Remove the amplifier by sliding it towards the left side of the chassis and lifting it out.

5. The amplifier may be replaced using the reverse of these steps.

6. Check the amplifier's associated 3 amp fuse. See Figure 6-2. Replace fuse if blown.

7. After an amplifier has been replaced, recalibrate its gain potentiometer. See Section 4.

6.4.3 DC SUPPLY TESTING/REMOVAL/REPLACEMENT

If a fault has been found that requires the replacement of the DC Supply module (DC Supply Assembly 4008-712), use the following procedure. See Figure 6-3.

6.4.3.1 TESTING

Use these tests to verify that the DC supply module is working correctly.

WARNING

Component voltages on the DC supply may reach 750 volts. Use caution not to touch uninsulated components and heat sinks.

WARNING

The high voltage supply on the DC supply module may be floating by as much as 200 volts above earth/chassis ground. Do not use an oscilloscope or other test instrument that may short any supply test point to earth/chassis ground.

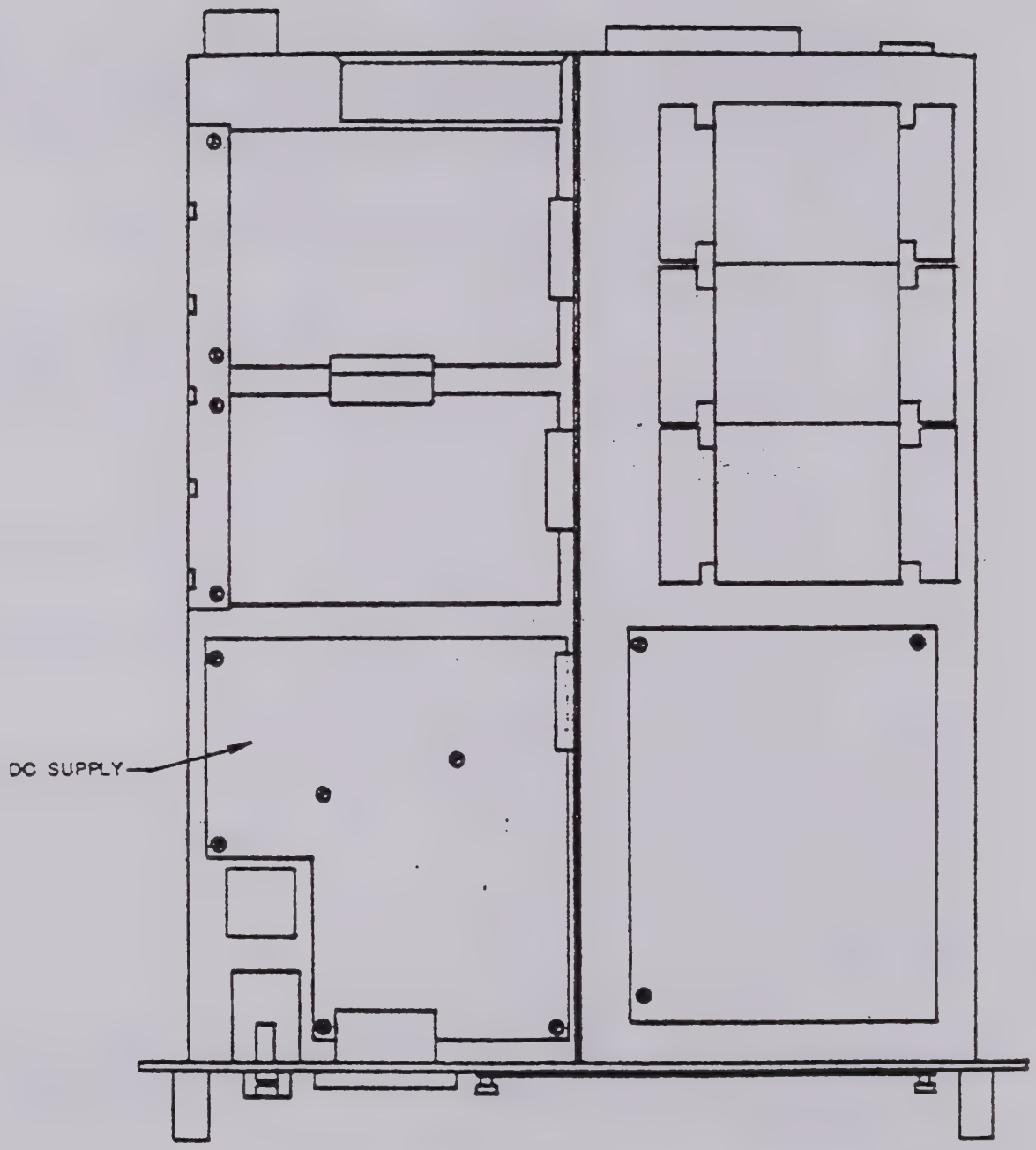


FIGURE 6-3
DC SUPPLY LOCATION

1. Turn the power source off.

2. Remove the power source top cover.

3. Turn the power source on and measure the following power supply DC voltages, see Figure 6-4.

TEST POINT	REFERENCE	DC VOLTAGE RANGE
TP-19	TP-18	+245 to +360
TP-1	TP-2	+18 to +31
TP-3	TP-2	-18 to -31
TP-4	TP-2	+8.5 to +14
TP-17	TP-2	+4.8 to +5.2
TP-5	TP-6	+8.0 to +14
TP-7	TP-6	+15 to +25
TP-8	TP-6	-15 to -25
TP-16	TP-6	+13 to +16
TP-11	TP-12	+48 to +55

6.4.3.2 REMOVAL/REPLACEMENT

If one or more of the supply voltages have failed, the DC supply module must be replaced. Use the following procedure for removal and replacement. See Figure 6-5.

WARNING

Filter capacitors on the DC supply module may be charged to 360 volts DC. These capacitors are bled down by resistors on the module. Do not attempt to remove the module until it has been allowed to discharge for at least two minutes.

1. Disconnect line power at the 1503L input TB-1.

2. Remove the power source top cover.

3. If the power source is configured for the low input voltage range the following wires must be removed from the DC supply:

WIRE #	DC SUPPLY POINT
4008-050-007	E1
4008-050-005	E2
4008-050-006	E3
4008-050-009,010	E5
4008-050-008	E6
4008-050-011	E7

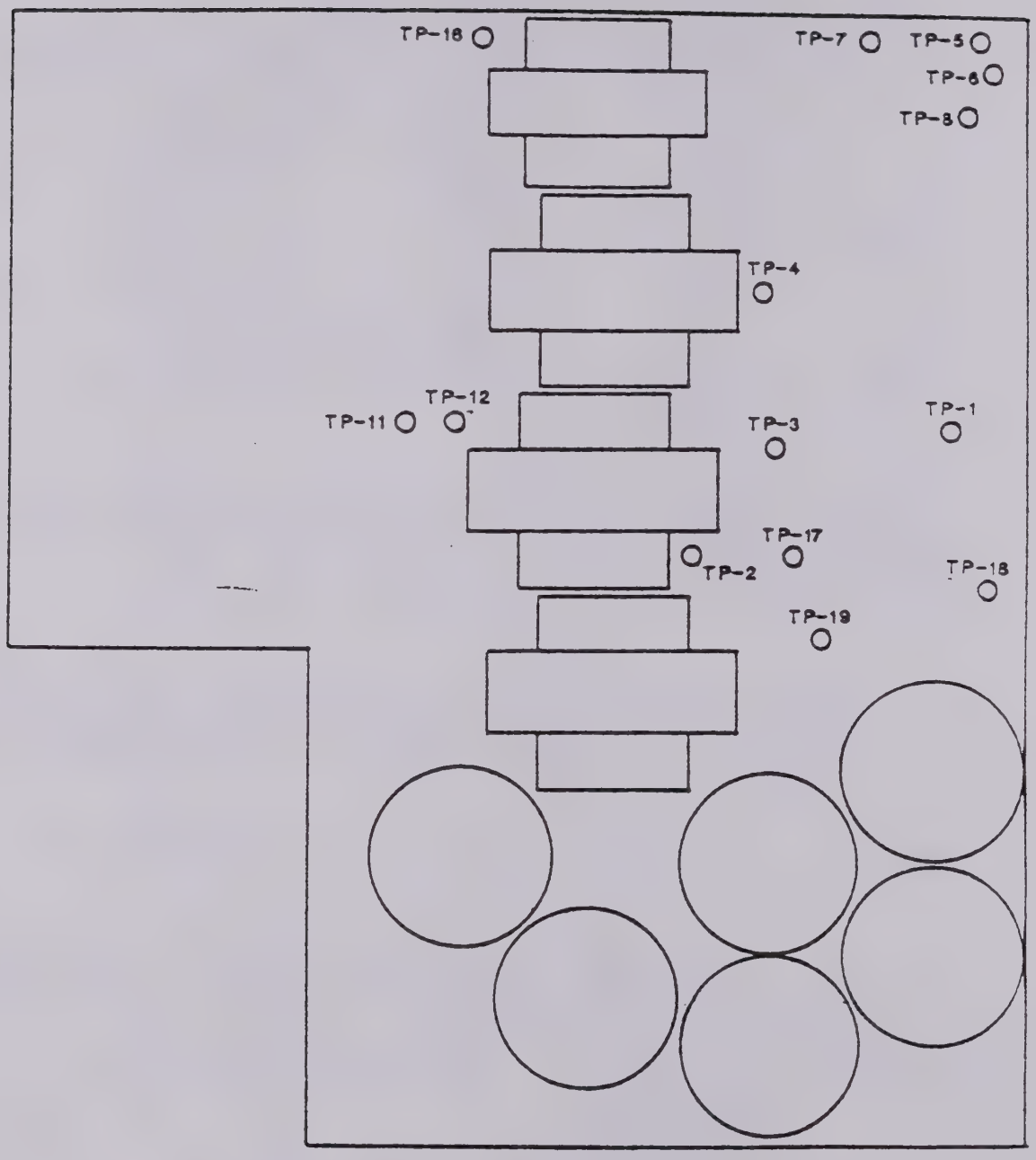


FIGURE 6-4

DC SUPPLY TEST POINTS

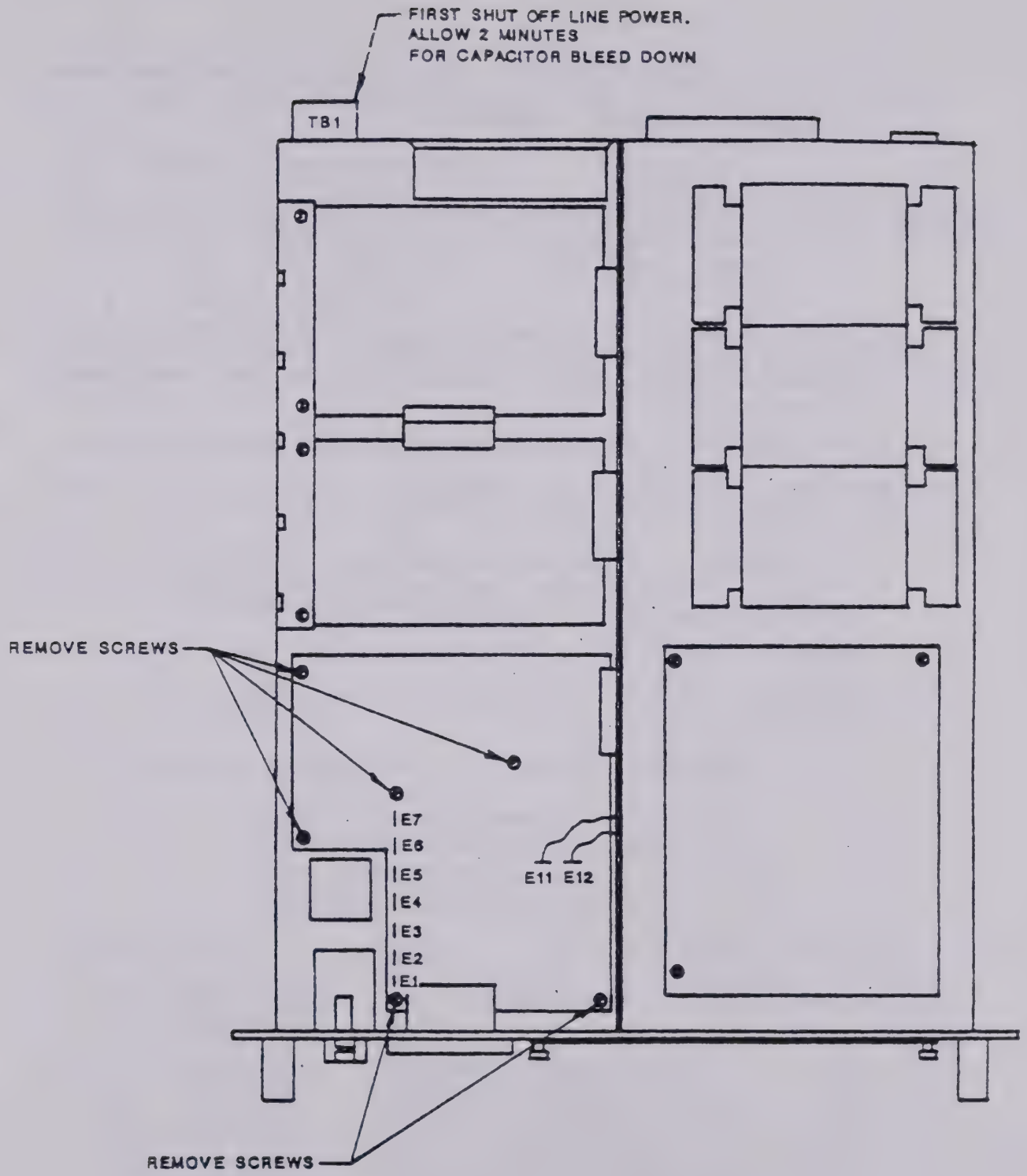


FIGURE 6-5

DC SUPPLY REMOVAL

4. If the power source is configured for the high input voltage range the following wires must be removed from the DC supply:

WIRE #	DC SUPPLY POINT
4008-050-007	E1
4008-050-006	E3
4008-050-011	E4
4008-050-009,010	E5
4008-050-008	E6

5. Disconnect the lead marked E11 on the DC supply at E1 on the power source mother board. Disconnect the lead marked E12 on the DC supply at E2 on the power source mother board.

6. Remove the 6 #8 screws that hold the DC supply in place.

7. Unplug and lift the DC supply module from the power source.

8. The module may be replaced by using the reverse of these steps. Reconfigure the input voltage range of the DC supply module if necessary. See Section 2.3.

SECTION 7

REPLACEABLE PARTS

7.1 GENERAL

This section contains ordering information and a list of replaceable parts. The list includes the parts description and California Instruments part numbers.

7.2 ORDERING INFORMATION

In order to ensure prompt, accurate service, please provide the following information, when applicable, for each replacement part ordered.

a. Model number and serial number of the instrument.

b. California Instruments part number for the subassembly where the component is located. (PARENT ITEM NO.)

c. Component reference designator. (SEQ NO.) p73

d. Component description.

e. Component manufacturer's FSCM number. (VENDOR)

f. California Instruments part number. (COMPONENT ITEM NO.)

All replaceable part orders should be addressed to:

California Instruments
Attention: Parts Department
9689 Towne Centre Drive
San Diego, California 92121

PARENT ITEM NO.: 4008-409 TOP ASSY, REPLACEABLE PARTS

SEQ NO.	COMPONENT ITEM NO.	DESCRIPTION	VENDOR	QTY
A1	4008-711-1	PC ASSY, METER/DISPLAY	16067	1
A3	4008-715-1	PC ASSY, MOTHER,POWER	16067	1
A4	4008-712-1	PC ASSY, DC SUPPLY	16067	1
A6	4008-718-1	PC ASSY, RANGE/RELAY	16067	1
A7	4008-410-1	AMPLIFIER ASSY, PHASE ABC	16067	1
A8	4008-410-1	AMPLIFIER ASSY, PHASE ABC	16067	1
A9	4008-410-1	AMPLIFIER ASSY, PHASE ABC	16067	1
A10	4008-720-1	PC ASSY,MOTHER CONTROL	16067	1
A11	4008-719-1	PC ASSY,CUR LIMIT	16067	1
A12	4008-707-1	PC ASSY,EXTENDER,OSC.	16067	1
A20	4007-407-3	MODULE ASSY, OSC,MANUAL	16067	1

PARENT ITEM NO.: 4008-715-1 PC ASSY, MOTHER, POWER
REPLACEABLE PARTS

SEQ NO.	COMPONENT ITEM NO.	DESCRIPTION	VENDOR	QTY
F1	270156	FUSE, 3A, 250V, 312003	75915	1
F2	270156	FUSE, 3A, 250V, 312003	75915	1
F3	270156	FUSE, 3A, 250V, 312003	75915	1

Appendix A

Number	Vendor Name	City	State
0000A	Electricord	Westfield	PA
0000C	Jackson Bros.	Waddon,Surrey	GB
0000S(28564)	OPCOA (Refoc Elect. Corp.)	Winsted	CT
0000W	Hilton Boss Co.	Southampton	PA
0000X(52745)	Tiaco	Los Angeles	CA
0004C	Itac	Santa Clara	CA
0004D(55112)	Plessey (Westlake Cap. Inc.)	Westlake Village	CA
0004G	LaFrance	Philadelphia	PA
0004M(54363)	Jan Crystal	Ft. Myers	CA
0004L(53495)	Data Components, Inc.	Gardena	CA
0004M	Erawa & Helmer	Santa Monica	CA
0004M	Ritz Instrument Transformer	Redondo Beach	CA
0004S	Switches Incorporated	Mt. View	CA
0004T(62643)	United Chemi-Con	Rosemont	IL
0004Q	JMJ Technical Prod. Inc.	Kendall Park	NJ
0004V(61837)	Semi Processes, Inc.	San Jose	CA
0004W	Hirose	Chatsworth	CA
0004X(63078)	Aptronics	Mentor	OH
0004T	Silicon Power Cube Corp.	Long Beach	CA
0004Z(61271)	Fujitsu	Santa Clara	CA
0008A(61964)	Omron Electronics, Inc.	Schaumberg	IL
0008B	Hallmark Metals, Inc.	Glendora	CA
0008C	Toshiba America, Inc.	Tustin	CA
0008D(55982)	Electronic Essentials	Woodside	NY
0008E(57856)	Kel-Am	Elkton	MD
0008F(55285)	Berquist	Minneapolis	MN
0008G	Panasonic	Secaucus	NY
0008H	Century Components	Canyon Country	CA
0008I(54186)	Micro Power Systems	Santa Clara	CA
0008J(46776)	Robinson Nugent	New Albany	IN
0008L(13150)	Beau Products (Varaitron)	Lacomia	NH
0008M(91725)	Corebinder (Garrard AJ & Co.)	Des Plaines	IL
0008O	Mitsubishi Electronics Amer.	Sunnyvale	CA
0008P	Silicon Power Cube	Long Beach	CA
0008R	Secme	Segnelet	France
0008S	Panel Components Corp.	Santa Rosa	CA
00544	Metal-Cal Div., Avery Prod.	Inglewood	CA
00779	AMP Inc.	Harrisburg	PA
00853	Sangamo Electronic Co.	Pickens	SC
00866	Gow Eng. Co., Inc.	City of Industry	CA
01002	G.E. Co., Ind. & Pwr. Cap. Dept.	John St. Hudson Falls	NY
01121	Allen-Bradley Co.	Milwaukee	WI
01139	G.E. Co., Silicone Prod.	Waterford	NY
01295	Texas Instruments	Dallas	TX
01961	Pulse Engineering, Inc.	San Diego	CA
02111	Spectrol Electronics	City of Industry	CA
02113	Collcraft, Inc.	Cary	IL
02335	Fairchild Controls Corp.	Hicksville,LI	NY
02375	American Insulating Mach. Co.	Philadelphia	PA
02534	Texas Electronics Co.	Dallas	TX
02660	Amphenol Corporation	Broadview	IL
02768	Illinois Tool Works, Inc.	Des Plains	IL
02799	Use Code 472136		
03507	General Electric Company	Syracuse	NY
03508	General Electric Company	Syracuse	NY
03797	Eldema Corporation	Compton	CA
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolls	NJ
03911	Clairex Corporation	New York	NY
04009	Arrow-Hart and Hegeman Elec.	Hartford	CT
04099	Capco, Inc.	Grand Junction	CO
04713	Motorola Semiconductor Prod.	Phoenix	AZ
04729	Universal Components Corp.	Green Brook	NJ
04963	3-M	St. Paul	MN
05245	Corcom Inc.	Chicago	IL
05276	Pomona Electronics., Inc.	Pomona	CA
05397	Ecmet, Union Carbide Corp.	Cleveland	OH
05791	Lyn-Tron, Inc.	Burbank	CA
05820	Wakefield Engineering, Inc.	Wakefield	MA
05972	Loctite Corp.	Newington	CT
06383	Pandelt Corp.	Tinley Park	IL
06514	Stantron, Wyco Metal Prod.	N. Hollywood	CA
06540	Amaton Elect. Hardware	New Rochelle	NY
06665	Precision Monolithics Inc.	Santa Clara	CA
06776	Robinson Nugent, Inc.	New Albany	IN
06915	Richco Plastics, Co.	Chicago	IL
07068	Kelvin Electric Company	Van Nuys	CA
07263	Fairchild Camera & Instr.	Mt. View	CA
07387	Birtcher Corporation	Los Angeles	CA
07556	Unitrack Colabora Plastics	Upper Derby	PA
07633	Epoxy Prod. Co., Allied Prod. Corp.	New Haven	CT
07707	USM Corp. (USM Fastener Div)	Shelton	CT
07716	IRC Incorporated	Burlington	IA
07910	Use Code 115818		
08026	Loctite (Auto & Consumer Grp)	Mtn View	CA
08057	Spang Ind. (Magnetics Div)	Sandy Lake	PA
08065	Accurate Rubber and Plastics	San Diego	CA
08261	Spectra Strip (Amphenol)	Garden Grove	
08289	Allen Delbert Co.	Pomona	CA
08353	Bristol Co. of Canada	Toronto, Ont	Canada
08730	Ostby & Barton (Vemalloc Prod. Div.)	Warwick	RI
08779	Signal Transformer	Bronxlyn	NY
09214	GE (Semiconductor Prod. Div)	Auburn	NY
09353	C & E Components	Newton	MA
09922	Burndy Corp.	Norwalk	CT
10389	Chicago Switch	Chicago	IL
11815	Cherry/Textron (Fastener Div)	Santa Ana	CA
12408	Elpac Electronics	Santa Ana	CA
12697	Clarostat Mfg.	Dover	NH
13103	Thermalloy Company	Dallas	TX
13150	Vernitron Corp (Beau Prod.)	Lacomia	NH
13684	Sperry Corp. Elec. Systems	Great Neck	NY
13919	Berr-Brown	Tucson	AZ
14099	Semtech Corporation	Newbury Park	CA
14604	Elwood Sensors Inc.	Cranston	RI
14655	Cornell-Dubilier Elect. Corp.	Newark	NJ
14726	Bollingsworth Co.	Phoenixville	PA
14752	Electro Cube, Inc.	San Gabriel	CA
14908	Electronic Instrument and Specialty Corp.	Stoneham	MA
15238	ITT Semiconductors	Lawrence	MA
15454	Ametek Ent (Bodon Div)	Anaheim	CA
15436	Elec-trol	Northridge	CA
15801	Fenwall Electronics	Framingham	MA
15818	Analog Teledyne, Inc.	Mt. View	CA
15912	Analog	Los Angeles	CA
16067	California Instruments Co.	San Diego	CA
16758	Delco Radio Div., Gen. Mtrs.	Kokomo	IN
16956	Semicon	Framingham	MS
17856	Siliconix, Inc.	Santa Clara	CA
18076	Vactec	City of Industry	CA
18178	Vactec, Inc.	Maryland Heights	MO
18310	Concord Electronics Corp.	New York	NY
18324	Signetics	Sunnyvale	CA
18613	Vishay Instruments, Inc.	Malvern	PA
18677	Sramba Mfg. Co. (Iero Corp.)	Monterey Park	CA
18722	RCA	Mountaintop	PA
18736	Voltronics Corp.	Kanarvec	NJ
19080	Robison Company	Hawthorne	CA
21604	Buckeye Stamping Company	Columbus	OH
21845	Solitron Devices (Semi-conductor Group)	Riviera Beach	FL
22599	Electric Step Mat Corp.	Van Nuys	CA
23450	Product Components Corp.	Hastings-on-Hudson	NY
23936	Pametor, Inc.	San Francisco	CA
24011	ECC	Burlington	MA
24355	Analog Devices, Inc.	Norwood	MA
24444	General Semiconductor Inc.	Tempe	AZ
24796	Farnico, Inc.	Paramount	CA
24931	Specialty Connector Co., Inc.	Greenwood	IN
24972	AEG-Telefunken Corp.	Somerville	NJ
25403	Amperex Electronic Corp.	Slatersville	RI
25497	Meter Master	Los Angeles	CA
26405	Marathon Electric Mfg. Corp.	Bowling Green	OH
26806	American Isotier, Inc.	Costa Mesa	CA
27014	National Semi-Conductor Crp.	Santa Clara	CA
27191	Cutler-Hammer, Inc.	Milwaukee	WI
27264	Molex	Downers Grove	IL
27335	B & B Motor & Control Corp.	New York	NY
27556	INA Electronic Products	Santa Fe Springs	CA
27683	Vare, Inc.	St. Garland	TX
27735	P-Dyne Electronics	Bridgeport	CT
27832	Hughes Aircraft	Newport Beach	CA
28480	Hewlett-Packard Co.	Palo Alto	CA
28520	Heyman Mfg. Company (Heycol	Kenilworth	NJ
28606	Echlin Ltd.	Rexdale Ont.	Canada
29372	Rexnord Inc. Tridair Ind.	Torrance	CA
29593	Busaco Eng. Inc.	El Segundo	CA
30039	International Components Crp.	Asbury Park	NJ
30161	Aavid Engineering, Inc.	Laconia	NH
30497	Dorman Company	Sylmar	CA
30983	Electra/Midland (Mepco/ Electra)	San Diego	CA
31027	Budvig Mfg. Co.	Ramona	CA
31951	Tridigo, Inc.	Pittsburg	PA
32293	Intersil	Cupertino	CA
32559	Bivar, Inc.	Santa Ana	CA
32997	Bourns Inc. (Trimpot Div)	Riverside	CA
33005	Jewell Electrical Inst. Inc.	Manchester	NH
33335	Logic Dynamics, Inc.	Gardena	CA
33716	Klingshaber Murray Co.	Los Angeles	CA
33855	Ducommun, Inc.	Los Angeles	CA
33901	Colbar Corp.	Irvington	NJ
34238	Mills Resistor Co.	Los Alamitos	CA
34323	Silicon General	Westminster	CA
34449	Intel Corporation	Santa Clara	CA
35607	Aerovox Canada Ltd.	Amherst NS	Canada
37964	Linear Technology, Inc.	Burlington, Ont	CAN
44655	Ohmite Manufacturing Co.	Skokie	IL
45722	Parker-Kalon	Clifton	NJ
46384	Penn. Eng. and Mfg. Corp.	Doylestown	PA
50157	Midwest Components, Inc.	Hustepon	RI
50522	Monsanto, Electronic Special Products	Cupertino	CA
50558	Electronic Concepts, Inc.	Eatontown	NJ
50811	Monster Corp.	Santee	CA
51167	Acies Electronics, Inc.	Frenchtown	NJ
51506	Accurate Screw Machine Co.	Butler	NJ
51705	ICO/Rally	Palo Alto	CA
52072	Circuit Assembly Corp.	Costa Mesa	CA
52745	Tiaco	Los Angeles	CA
53076	Elmtec, Inc.	Buffalo	NY
53495	Data Components, Inc.	Gardena	CA
54361	Edwards Sheet Metal Works	Fredericktown	OH
54407	Power-One Co.	Camarillo	CA
55322	Zaotel, Inc.	New Albany	NY
55566	BAF Electronic Hardware, Inc.	Seymour	CT
56289	Sprague Electric Company	North Adams	MA
56637	RCD Components, Inc.	Manchester	NH
57640	United Chem-Con Corp.	Philadelphia	PA
57856	Kel-Am, Inc.	Elkton	MD
58474	Superior Electric Company	Bristol	CT
59730	Thomas and Betts Company	Elizabeth	NJ
59993	International Rectifier Semiconductor Div.	El Segundo	CA
60395	Xicor, Inc.	Milpitas	CA
61394	Beeng Technology, Inc.	San Jose	CA
61441	Zeromic	Palo Alto	CA
61529	Aromat Corp.	Mountainside	NJ
61735	Pulse Engineering, Inc.	College Park	MD
62483	Semicron Corp. of America	Torrance	CA
62643	United Chemicon, Inc.	Rosemont	IL
62786	Hitachi America Ltd.	San Jose	CA
63743	Ward Leonard Electric Co.	Mt. Vernon	NY
63791	Stac Micronics, Inc.	New York	NY
70318	Allmetal Screw Prod. Co.	Garden City	NY
70903	Belden Manufacturing Co.	Chicago	IL
71210	Dod Industries, Inc.	Willoughby	OH
71279	Cambridge Thermionic Corp.	Cambridge	MA
71400	Bussman Mfg. Div. McGraw-Edison, Co.	St. Louis	MO
71450	CTS Corporation	Elkhart	IN
71468	ITT Cannon Electric, Inc.	Los Angeles	CA
71590	Centralab Div. Globe-Union	Milwaukee	WI
71707	Coto-Coil	Providence	RI
71744	Chicago Miniature Lamp Works	Chicago	IL
71785	Cinch Manufacturing Company	Chicago	IL
71984	Dow Corning Corp.	Midland	MI
72136	Elmwood (Electro Motive)	Willimantic	CT
72619	Dialight Corporation	Brooklyn	NY
72699	General Instruments	Newark	NJ
72982	Erie Technological Prod. Inc.	Erie	PA
73138	Beckman Instruments, Inc.	Fullerton	CA
73612	Consolidated Electronic Wire and Cable Corp.	Chicago	IL
73734	Federal Screw Products, Inc.	Chicago	IL
74193	Heinemann Electric Company	Trenton	NJ
74545	Harvey Hubbell, Inc.	Bridgeport	CT
74868	Illinois Condenser Co.	Chicago	IL
74970	E.F. Johnson Company	Waseca	MN
75042	ITW Electronic Components	Philadelphia	PA
75382	Eaton Electric Corporation	Mt. Vernon	NY
75582	Leviton Mfg. Co.	Little Neck	NY
75915	Littlefuse, Inc.	Des Plaines	IL
76385	Minor Rubber Co., Inc.	Bloomfield	NJ
77068	Panel Eng.-Equipment Co.	Elizabeth	NJ
77122	United-Carr Inc., Potvin Div	Watertown	CT
77342	Potter and Brumfield Div, AMF	E. Princeton	IN
78189	Shakeproof Div, IL Tool Works	Chicago	IL
78553	Timmerman Products, Inc.	Cleveland	OH
79136	Sloan-Servitto Products Corp	Chicago	IL
79136	Valdes Robinaer Inc.	Long Island City	NY
79963	Zierick Mfg. Corp.	New Rochelle	NY
80031	Mepco/Electra	Morristown	NJ
80223	United Transformer Co.	New York	NY
80294	Bourns, Inc.	Riverside	CA
80495	High Voltage Engineering Corp (Anderson Pwr Prod. Div)	Brighton	MA
81095	Triad Transformer Corp.	Venice	CA
81312	Winchester Electronics	Oakville	CT
81348	(Fed. Specs) Promulgated by General Services Administration Washington DC		
81349	Military Specification or Commercial Generic Number		
81541	Airpax Corp.	Cambridge	MD
81603	Rocs Products Co.	Chicago	IL
81951	Hamilton-Harris Mfg Co.	Llewellyn	PA
82164	Standard Grigsby	Aurora	IL
82389	Switchcraft, Inc.	Chicago	IL
82877	Betron Mfg. Co., Inc.	Woodstock	NY
82893	Vector Electronics, Inc.	Sylmar	CA
83330	Herman H. Smith, Inc.	Brooklyn	NY
83446	Elco Tool & Screw Corp.	Rockford	IL
85400	Brady W.H. Co.	Milwaukee	WI
86684	RCA	Harrison	NJ
86928	Seastrom Mfg. Co., Inc.	Glendale	CA
87034	Marco-Oak Industries	Anaheim	CA
88245	Deece Div., Litton Ind.	Van Nuys	CA
90201	Mallory Capacitor Co.	Indianapolis	IN
91506	Amgat, Inc.	Attleboro	MA
91637	Dale Electronics, Inc.	Columbus	NE
91662	Elco Corporation	Willow Grove	PA
91802	Industrial Devices, Inc.	Edgewater	NJ
91833	Keystone Electronics Corp.	New York	NY
91947	National Tel-Tronics	Woodville	PA
92194	Alpha Wire Corp.	Elizabeth	NJ
93303	Pentagon Products Co.	Washington	DC
94222	Southco, Inc.	Lester	PA
94496	Magnecraft Electric Co.	Chicago	IL
95146	Alco Electronic Prod., Inc.	No. Andover	MA
95193	RCA	Cincinnati	OH
95354	Methode Manufacturing Corp.	Rolling Meadows	IL
95566	Arnold Engineering Co.	Marengo	IL
95987	Wechsler Company, Inc.	Chicago	IL
96906	Military Std		
97535	Electronic Engineering Co.	Santa Ana	CA
98159	Rubber Tech, Inc.	Gardena	CA
98291	Sealectro Corp.	Mamaroneck	NY
98376	Ecco Mfg. Co. (West)	Burbank	CA
98378	ICMC	Burbank	CA
99017	Protective Closures Co., Inc. (Caplugs Div)	Buffalo	NY
99217	Bell Industries, Inc.	Delavan	WI
99742	Perancell	New Brunswick	NJ
99761	IMC	Haywood	CA
99900	Delevan Electronics Corp.	Aurora	NY

ONE YEAR WARRANTY

CALIFORNIA INSTRUMENTS CORPORATION warrants each instrument manufactured by them to be free from defects in material and workmanship for a period of one year from the date of shipment to the original purchaser. Excepted from this warranty are fuses and batteries which carry the warranty of their original manufacturer where applicable. CALIFORNIA INSTRUMENTS will service, replace, or adjust any defective part or parts, free of charge, when the instrument is returned freight prepaid, and when examination reveals that the fault has not occurred because of misuse, abnormal conditions of operation, user modification, or attempted user repair. Equipment repaired beyond the effective date of warranty or when abnormal usage has occurred will be charged at applicable rates. CALIFORNIA INSTRUMENTS will submit an estimate for such charges before commencing repair, if so requested.

PROCEDURE FOR SERVICE

If a fault develops, notify CALIFORNIA INSTRUMENTS or its local representative, giving full details of the difficulty, including the model number and serial number. On receipt of this information, service information or a Return Material Authorization (RMA) number will be given. Add RMA number to shipping label. .Pack instrument carefully to prevent transportation damage, affix label to shipping container, and ship freight prepaid to the factory. CALIFORNIA INSTRUMENTS shall not be responsible for repair of damage due to improper handling or packing. Instruments returned without RMA No. or freight collect will be refused. Instruments repaired under Warranty will be returned by prepaid surface freight. Instruments repaired outside the Warranty period will be returned freight collect, F.O.B. CALIFORNIA INSTRUMENTS, San Diego, CA. If requested, an estimate of repair charges will be made before work begins on repairs not covered by the Warranty.

DAMAGE IN TRANSIT

The instrument should be tested when it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed immediately with the carrier. A full report of the damage should be obtained by the claim agent, and a copy of this report should be forwarded to us. CALIFORNIA INSTRUMENTS will prepare an estimate of repair cost and repair the instrument when authorized by the claim agent. Please include model number and serial number when referring to the instrument.

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